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MANAGEMENT SERIES
L. C. MORROW, *Consulting Editor*

HOW TO CHART TIMESTUDY DATA

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L. C. MORROW, *Consulting Editor*

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HOW TO CHART TIMESTUDY DATA

BY

PHIL CARROLL

Professional Engineer
Author
"Timestudy for Cost Control"
"Timestudy Fundamentals for Foremen"
"How to Control Production Costs"

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HOW TO CHART TIMESTUDY DATA

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To those who

STRIVE

for better timestudy and incentives

PREFACE

For years this book has been on my mind. I have wanted to set down the ideas behind some of the "trick charts" originally included in "Timestudy for Cost Control." The urge was increased when someone said, "Accuracy in simple arithmetic through decimals (as minimum mathematical qualification for a timestudy man) is not consistent with the complex chartings shown in your book." Essentially, then, this book is an expansion of Chaps. 13, 14, and 15 of my first one.

Charting can be almost entirely graphical. As you will see, anyone can make most types if he can add two plus two and get the right answer. This is an important point with me. Most of the timestudy men I have had the pleasure of working with have come from the molding floor, the assembly bench, and the production machines. Amazingly, they seem to enjoy chart making more than any other phase of training. Perhaps that is because they have a high degree of structural visualization.

Whatever the reason, charting is interesting. It is profitable, also. It has afforded the way to set standards economically for job shop operations where most of my experience has been. You may say that this type of charting was developed out of necessity. The one- and two-piece order problems forced me to find cost-cutting methods in standard setting.

The ideas brought out in the book represent an accumulation since 1924. At that time, my first chart was worked out. As you look at it, and at others, you will see nothing unusual. As a matter of fact, most of the ideas are relatively commonplace. Yet these charting methods, except for nomographs, have not been found in the books I have searched. Consequently, the industrial engineer may find some value in having them brought together and written down.

Many variations have been suggested to me by associates and client personnel. These men deserve much of the credit for whatever development may be reflected here. Specific mentions are made in the text of those men I can identify with the ideas. Yet the material in this book is little more than suggestive. Meager as a general explanation must be, it is my hope that the fundamentals will prove helpful. Your criticisms are welcomed. Comments on both omissions and commissions will be very much appreciated.

What we have here has been a long time under way. My daughter Margaret worked on parts of it for a whole summer after she first learned to type. My daughter Jeane drew the sketches while taking her courses in art. Charles A. Thomas, Jr., made some nomographs before he ever thought of becoming my assistant. In its completion, Charlie and my secretary, Miss Atlee O'Brien, have worked out many of the illustrations. Their helpful criticisms, and meticulous efforts in correct detailing, have made it possible to bring the manuscript to its present conclusion.

PHIL CARROLL

MAPLEWOOD, NEW JERSEY
August, 1950

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CHAPTER 1

THE WHY OF INCENTIVES

"A fair day's pay for a fair day's work" is our most common way of expressing the basic rule of wage payment. A "fair exchange" is the same basis we use in all our shopping for day-to-day necessities. We buy food, clothing, and other things at prices we feel we can afford. We get large or small quantities according to our needs. We consider the quality as it relates to what we want.

In reverse, the businesses that produce, transport, and sell the things we buy have to supply the goods we want at prices we are willing to pay. Each of these businesses—call them converters, if you like—probably adds some labor, material, and overhead at each of the successive stages passed through in reaching us, the consumers. What we are willing to pay determines how much money the converter has to work with. If it is not enough, he will go out of business unless he can bring his costs down sufficiently to make a profit. He may go broke anyway. His friendly enemy, competition, may take our business away from him because of higher quality or better service or, sometimes, more courtesy.

Essentially, however, the converter is a consumer the same as each of us. He buys our labor. But too often, there is a very fundamental difference when the direction of the exchange is reversed. Frequently, we sell our time at so much per hour, week, or month, without regard to how much we turn out for that pay. Obviously, much of our work cannot be measured by the pound or the piece. And yet, when we buy the results of our work, we insist that we get a pound or a piece of a certain quality. We will buy only in terms of quality and quantity at a price, in the final analysis.

LABOR, MATERIAL, AND OVERHEAD

Naturally, many factors enter into the prices we pay. Generally speaking, three are important. These are labor, material, and overhead. Material and capital costs would be about the same for competing firms under normal circumstances. But the labor and overhead costs would probably be very different for two reasons. One is the cost difference due to the relative degree of tooling. The other is the "efficiency" of performance. Differences in wage rates might be a third reason, but with the tendencies toward a more universal use of proper job and position evaluation, we can overlook this variable in our discussion.

LABOR COSTS AND METHODS

Even with reasonably uniform wage rates, the labor and overhead costs may be almost any amounts, depending upon the rate of productivity of the employees—all of them—and the methods used in working. These two factors modify each other somewhat. For example, the methods used have a considerable bearing on the output. Also, as a rule, the better the methods, the higher the overhead costs and the lower the labor costs per unit. But capital invested in better methods does not necessarily bring about a net reduction in cost. Maybe the overhead cost rises disproportionately. Perhaps the labor cost does not decline as it should with method changes. Again, there may be a third unknown present. We may not know what the labor costs actually are either before or after the method changes are introduced.

UNIT LABOR COSTS

Consequently, more facts are needed. And the large unknown in many businesses is the labor cost per unit. Most of the other elements of cost are known because they are for goods or services purchased directly or *indirectly*. The word "indirectly" refers to costs like depreciation computed and allocated from a capital outlay.

We need to know unit labor costs for several important reasons:

1. To find out whether the product is manufactured and sold at a profit or at a loss
2. To predetermine so far as possible the gains and losses to be derived from proposed changes in methods, materials, and products
3. To control the costs of labor with respect to the methods, products, and volumes currently in operation

Very often, labor cost is the largest element of expense in the business. Often, also, it is the greatest variable. It varies for many reasons. Chief of these are lack of control and absence of measurement. Perhaps there is no effective cost control because there is little or no measurement.

LABOR MEASUREMENT

It is necessary, then, to measure labor in order to know what part of cost it is and to properly reward extra efforts. This does not mean that part we call direct labor. We need both measurement and incentive for all labor. Nor does it imply that labor is simply another commodity. The basic truths are two. First, people want to be paid for what they do, and this cannot be done fairly without some way of measuring results accomplished. Second, the success of the business cannot be maintained indefinitely with one large cost factor remaining unknown and unpredictable.

This points to the social and economic values of good wage incentive. Rewards are inseparable from labor measurement if the incentive is to be positive. In other words, standards set for the "fair day's work" are of little constructive value if their attainment only determines that the employee can continue to hold his job. The fear mechanism is a strong enough incentive, but it is a negative and wasteful one.

We talk about the ever-present tendency to criticize when things go wrong while omitting the pat on the back for the job well done. Why then do some plants persist in using wage payment methods that force layoff or transfer when the job performance is not acceptable and yet provide no way to reward extra production "beyond the call of duty"?

True, there is the constructive outlet of promotion. This is present in both "day rate" and wage incentive payment methods. But, promotion is open to only part of the organization. Moreover, promotion is relatively a large step. The in-between gradings should be provided by incentive payments. These bring in the flexibility necessary to fairly compensate those who do more than the fixed wage calls for, but who may be incapable of holding or getting the next higher job.

WAGE INCENTIVE DEFINED

Everything we do has some kind of incentive behind it. Incentive is the urge to accomplish. It may be that we seek more honor, more skill, or more money. All these add up to getting ahead, as each of us may view it. This point becomes increasingly important every time we say "We must recognize the man as an individual." Recognition includes much more than a cheerful "Good morning." To me, it means due consideration of applied skill and ability. But any kind of merit review can be criticized as being based on mere opinion. For this reason I maintain that we need measurements, and incentive rewards to go with them.

Sound wage incentive is a method for paying full value for extra effort beyond the timestudy standards set equal to the base pay. It is a means for rewarding increases in productivity per man-hour. The English term "payment by results" perhaps more clearly expresses the meaning intended. The definition excludes the opposites labeled "incentive" in newspaper headlines, during the Second World War. Then, we paid money to plough under the excesses of little pigs. Even now, we hear that people are being paid "not to produce" certain crops they had no intention of raising in the first place. In addition, we exclude here all devices for "sharing the wealth." Taking from the haves to give to the have-nots is far different from creating wealth. Getting out more production is the only way we can increase wealth. Only through greater productivity can we improve our standard of living. Increasing wages and salaries won't do it except momentarily.

PRODUCTIVITY OR PRODUCTION?

Of course, production can be increased by setting up more plants and more machinery. But these require large outlays of capital. The average investment was $8,000 per employee, according to Carl Snyder.[1] More investment in productive capacity should raise production. But that is production. Here, we are talking about productivity. The distinction is important. High productivity per man-hour is what put America so far out in front of the nations of the world.[2]

To make the point more vivid, suppose we had to double our plant capacity because our productivity dropped to half. Then twice as many people would be required to turn out the present amount of production. And the invested capital per unit of output would be more than doubled. I say "more than doubled" because plants and machines cost much more now with inflated dollars than they did prior to 1940.

[1] "Capitalism the Creator," The Macmillan Company, New York, 1940.

[2] Carroll, Phil, "An Engineer's Viewpoint of Incentive Compensation," Production Series No. 150, American Management Association, 1944.

INCREASING EARNINGS

Certainly money must be spent to make progress. That is true of methods improvement, another important factor in productivity. But neither investments in more plants nor expenditures for better methods insures increasing the earnings of those who produce more.[3]

There is a corollary to this. Let's express it in the words of a Works Manager who knew firsthand the before and after conditions. "You supervisors all remember how we used to lie awake nights planning ways to improve costs with better jigs and fixtures, newer machines and tools. Regardless of how much time and money we spent, we never once realized the full benefits we expected. The reason was that our men had no incentive to make our ideas work. They could sleep with one eye open and in one night figure out a dozen ways to defeat the full accomplishment of an idea we had spent several weeks trying to develop."

His experience told him that he needed also the interest of the man. Otherwise, some part of the improvement leaked away. So he introduced a wage incentive plan. He needed wage incentives to pay for greater productivity in a fair and orderly way. That is an important value of wage incentive, in my opinion. Good wage incentive benefits the individual employee through improvement in his standard of living. It provides more dollars to pay for cheaper products. In addition, it enables the individual to help himself get ahead in industry. It measures the amount industry should pay for improvements in skill and diligence.

Incentive results are determined largely by psychological factors. The arithmetic does nothing more than measure what did happen—not what can or could have happened. Past performances are no proof whatever of what can be done under the proper conditions. People should not argue about the advantages and disadvantages of particular incentive plans until after they have defined in each case

1. The extent of time facts underlying the opinion
2. The extent of constructive action taken on the basis of those facts

We must remember that a sound incentive plan will point out errors in all parts of an organization. Maybe that is why some managements are as much against its use as others are in favor of it. Perhaps, too, that is why some labor groups seem to be as much in favor of using incentives as certain other groups are against it.

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[3] Carroll, Phil, Higher Productivity through Wage Incentives, *Modern Management*, April, 1947.

Proper wage incentives point out wasted time. They help to turn lost time into useful production. The result is a lower cost per unit for an increased number of units. From the savings, industry can pay higher earnings and sell at lower prices. Thus, with proper incentives we can bring about a doubly beneficial effect on real wages.

COST CONTROL

If you will agree to the basic soundness of wage incentives, we can further develop their usefulness in cost control. In this particular, the benefits accrue from three characteristics:

1. The better type of modern incentive plan establishes time standards equivalent to the work required of a normally qualified person when earning the properly evaluated wage set for the occupation.
2. The premiums earned are paid out 100 per cent proportionally for performances above the correctly established normal standard times.
3. The expectancy is that substantial incentive premiums will be earned regularly by almost all those included within the incentive plans.

From the foregoing, it is evident that labor costs of the work that is measured will be practically constant. Costs will vary but slightly, because the money paid is the same for each unit of output over standard. Thus the ideal of cost control can be realized for all the measured work. Besides, the labor costs are predictable with a high degree of certainty. This is exceedingly important for every progressive business. When probable labor costs can be predetermined, another important advantage is obtained. The improvements forced by the necessity to progress become less hazardous because probable costs and savings can be predicted. The hazards of continuing the successful life of a business are always present. Just as when a new product is considered, the number to be sold is indefinite. But the facility for predetermining labor cost is extremely valuable in removing that one factor from among the unknowns.

FUTURE COMPETITION

Another reason for measuring and rewarding all forms of labor effort is to provide for the meeting of future competition. This will come not only from within our country, but also from the many nations we have equipped and trained. It may be pessimistic to say that it looks as though it will come down to the survival of the fittest. Our staying ahead in the race to sustain a high degree of employment seems to depend upon steadily increasing our productivity per man-hour. Without that, continued employment will depend largely upon reducing costs by reducing wage rates. Such an alternative is not to anyone's liking.

We want to retain and even increase our incomes. But to stay in the business of world competition and also pay high wages requires an ever greater output per man-hour. It is right in here that wage incentive makes a very useful contribution. It makes for increased earnings and increased efficiency.

PRODUCTION TIMESTUDY

Naturally, wage incentive is not all milk and honey. Incentive is not a cure-all, nor is it simple. It is like any other human effort—we get no more out of it than we put into it. This factor alone partially explains the great range in degrees of success attained by different companies. Everyone should realize that to gain the tremendous advantages afforded by wage incentives he must take on certain disadvantages.

The chief difficulty brought on is the series of arguments about standard times. Some of the complaints have no foundation other than the insatiable urge to get more money by any means. These would not be directed against incentive standards if there were no incentive plan. But the abandonment of a plan or the refusal to institute one would not eliminate this form of pressure. It would be present just the same, but revealed in other forms. This you must remember.

The solution to arguments about incentive standards seems obvious. It is chiefly a matter of minimizing their number by using procedures that reduce errors. This form of solution points directly toward the use of good timestudy methods. Timestudy is much more reliable for setting production standards than any of the compromise or "guesstimate" methods. Timestudy is the best method we have worked out for determining what is a measure of a fair day's work. Coupled with sound position and job evaluations, it can be used to determine the fair day's pay.

Further development of timestudy results, to build up standard data, adds important advantages. Primarily, it reduces the problems of wage incentive administration by eliminating most of the inconsistencies in time standards. Also, standard data helps to reduce the number of difficulties arising because of incomplete coverage. It can be used economically to set up standards for new work and small-quantity operations where direct timestudy would be impractical. Finally, and perhaps most importantly, standard data can be used to fairly measure the work in many operations of the business where no two jobs are alike. This type of application, especially to indirect labor of many kinds, overcomes the objections raised by those who are too often excluded from the benefits of incentives.

Of course, not everyone can be measured and afforded incentive opportunities. No man-made invention works correctly all the time. But that is not a reason for refusing to utilize what we have to the fullest extent. So far as we can make the best use of the tools available, we can do the greatest good for the greatest number. And it seems self-evident that wage incentive is a tool of inestimable value to us in the highly competitive business of maintaining jobs for all who are willing to work. Therefore, here and in subsequent chapters, we will enlarge upon ways to extend the use of incentive plans. We will discuss further the principles and some of the mechanics of the standard data method.

GAINING CONSISTENCY

Perhaps the most pertinent advantage of the data method is the consistency of its results. "Consistency is more vital than accuracy."[1] So it is with both wage rates and incentive standards. In both, complaints occur because one job pays more than another relatively.

To iron out inequalities—to avoid inconsistencies—we are using job and position evaluation plans to determine base wages and salaries. This method is fundamentally sound. It attempts to build up the correct relative base rate by analyzing the elements of the job. In so doing, "points" or "factors" are allowed according to degrees for the several characteristics required by the job. The procedure is essentially the same as that called standard data by the timestudy man. He assigns element times according to degree, similarly as the job analyst assigns values for job characteristics. Both methods are used to arrive at values that are consistent with allowances made for all other types of work in a plant.

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[1] Carroll, Phil, "Timestudy for Cost Control," 2d ed., p. 23, McGraw-Hill Book Company, Inc., New York, 1943.

BASE WAGE PAYMENT

Essentially, the evaluated basic wage per hour, week, or month is intended to pay for skills, abilities, and a certain amount of effort considered necessary to the proper accomplishment of the job. Skill as an inclusive term, however, does vary with individuals working on a given job. It is often specified in terms of minimum requirement. Those having above-minimum skills deserve higher wages when more or better productivity is turned out. This may be made possible perhaps through promotion. Under this condition, basically again, a higher evaluation applies.

PAY FOR APPLIED SKILL

Payments for productivity must consider two main elements of contribution, namely, quality and quantity. These are called "skill" and "effort" by the timestudy man. Applied skill is a composite of the two elements. Both affect output. Both should be paid for. We should have the orderly means through wage incentives to pay for the plus skill and the plus effort.

In reality then, all wages should pay for applied skill. The basic wage should pay for a certain amount of work of a given class. Presumably, an increase pays for higher than normal output at that level, or for just a normal output of a higher class. But without something more than opinion to go on, there can be wide variations between fair rewards and actual output. That is why we need standards of measurement for output. They can automatically change the wages to compensate for variations in actual work done.

Wage incentive is not the cure-all for adjusted compensation any more than job evaluation answers all problems of base wage determination. However, wage incentive does more correctly take care of payments for many differences in output. And it is fair when it is set up properly and maintained consistently.

EXTENDING MEASUREMENTS

We can use wage incentive much more extensively than we have, to help solve the problems of fair wage compensation. We must extend and improve our incentive plans so that we can pay fairly for extra skill and extra effort. The field is very broad. Many enterprises have none at all. Some plants do not provide incentives for part of the employees whose friends and relatives are already earning extra pay. This situation presents the problems created by inconsistency. They must be solved.

Another problem exists because some jobs are on incentive and others are not. Work measurement for certain employees has not been completed. Many indirect employees have no incentive whatever. For both sets of conditions, earning opportunities are lacking. Comparisons are made. As a result, people feel that they are being treated unfairly. To hand out some part of the "make-up" is not the answer. This remedy creates more problems than it solves.

My belief is that we must provide the earning opportunities. In so doing, we avoid losing the respect of people who resent a dole of any sort. In addition, we supply an impersonal yardstick for measuring a person's applied skill and ability. That gives him a standing very much more satisfying than that of just another clock number.

In solving these problems, we gain other advantages. The one I want to emphasize is that of improved costs with cost control. The average method of costing and overhead allocation is extremely dangerous in competitive operations. More facts are necessary. These improvements and extensions cost money, obviously. But any business must spend money to advance. What the investments are made for, in the main, is determined by relative gains. Therefore, my efforts will be directed toward pointing out why investments in timestudy incentive have more possibilities for improving employee satisfaction, production costs, deliveries, and profits than many others. These are the elements of success in competition. To stay ahead of the parade, we have to take constructive action. Little choice is left if we fully understand the statement made by Don Copell at an AMA meeting. "Remember that no war, no strike, no depression can so completely and irrevocably destroy an established business as new and better methods in the hands of an enlightened competitor."

CHAPTER 2

SUCCESSFUL INCENTIVES

Extending an incentive plan is much the same as expanding a plant or a business. It costs money and effort. It involves risks. But the undeniable urge to get ahead often wins out. We can continue to grow just so long as we meet with success. What you call success with an incentive plan depends upon the objectives you have in mind. You may measure success in dollars. To some degree, the dollar measure can be applied. But dollar volume is a result. It is not a cause. Here, we are interested in the factors that bring about success.

Numerous elements may contribute to the success of an incentive application. Some have a major influence under certain conditions and only minor effects in others. In this discussion, we are concerned with two. The businesslike objective is to gain a fair return for the time and effort expended. This is the common-sense goal of any business venture. But let's not be misled. A few hours spent in figuring out some plant-wide bonus plan might reap enormous returns—for the time being. But you would have no costs or controls. And employee satisfaction, if any, would be temporary only. Considering sound costing as our first objective, the second is to obtain lasting employee satisfaction. You might argue that employee satisfaction comes first. But satisfaction might be short-lived if the business did not continue to make a reasonable profit.

EFFORT AND MONEY INVESTED

Both effort and money are invested in a sound incentive application. Effort is the expensive part, because a great deal of time must be spent to obtain success. Compared with other investments, efforts applied through timestudy with incentives will produce a much greater return than the average. The greater returns come from the reductions in management errors. This takes effort—lots of it. The errors to be corrected are delays, extra operations, and rework. The reduction of these wastes makes up the bulk of the so-called labor savings that result from the introduction of an incentive plan.

The amounts of delay, extra operations, and rework show up vividly when good timestudy is used. You want to pay particular attention to this detail. It is an important difference between sound timestudy standards and those, for example, set by a foreman to be used as piecework prices. You would be made very aware of the difference if your timestudy men were changing from piecework or Halsey 50-50 over to sound timestudy standards. They would repeatedly mention unnecessary elements that had been performed for years. You would have to be very careful to prevent these men from thinking they were "good." You would have to remind them constantly that they were the first ones ever paid to study the operations.

You will remember that the Halsey 50-50 plan was devised to escape the taking of timestudies. Some of the over-all plans put in during the Second World War were the quick and easy kind. Piecework is of the same type frequently. The wastes are buried in the "rates." Those who favor the simplified methods argue that the clerical costs for a more complicated system are much too great. More often than not, however, you will find that the emphasis has been placed on the wrong element of cost.

OVERHEAD COSTS

Whether the coverup is accidental or on purpose, it is very expensive. The thinking is limited to labor cost. As a result, the actual overhead per unit of output is greatly inflated. It may not look that way in the figures because the wastes are buried in the denominator. Overhead ratios can be very misleading. For instance, take 150 per cent as an overhead common in certain types of shops. This is equal to $1.50 overhead per $1.00 of labor. Now suppose that in the dollar of labor there is $.25 of the extras we have been discussing. These extras are overhead in reality. They do not add to the output. Therefore, let's put them where they belong and refigure the overhead. The $1.50 plus the $.25 in extras becomes $1.75 overhead. This $1.75 overhead when divided by the $.75 remaining in the labor-dollar denominator equals 233 per cent, a truer overhead rate. Now assume what is sometimes the case, namely, that there is $.50 worth of extras in the dollar of labor. Adding the $.50 of extras to the $1.50 of overhead makes the real overhead equal to $2.00. Under this supposition, the $2.00 of overhead, divided by the remaining $.50 of labor, results in a 400 per cent overhead.

But you say, "That is all theory." Maybe so. Nevertheless, many plants are laboring under the false delusion that they have low overhead. Very often the overhead depends upon the method of figuring. Can you remember when we used to charge the foreman's time to the job? To be clear in our own minds, we should think in terms of overhead per unit of output and not in terms of overhead per labor hour or labor dollar. Approaching the problem from that angle, you would have to exclude from labor many of the items that are actually indirect costs. At this point, you may ask, "What is the difference, whether there's low or high overhead? Why attempt to achieve truer ratios?"

For one reason, overhead cost is high and rising. It goes higher when we introduce timestudy, quality control, or planning. It goes up again when we introduce the pension plan, hospitalization, and three more holidays. It goes up still higher with every improvement in methods, equipment, and tooling.

"What does overhead have to do with timestudy?" may be your question now. Well, we are trying to stress one of the major differences between timestudy and "rate setting." Timestudy is an analytical process. It brings out into the open the numerous wastes of time. Also, we are trying to point out where an important part of the return comes from when really constructive efforts are invested in the installation and maintenance of a sound incentive plan. Looked at correctly, the arithmetic might indicate clearly that there are times when the savings in overhead may exceed those to be made in labor cost. Evidence of what can be done is brought out in the report by John W. Nickerson.[1] He shows vast differences between increases in productivity under incentive plans using past performance as contrasted with those using timestudy standards.

SAVINGS IN COST

These differences can have a big effect upon results. Increases in productivity and reductions in cost might be large at the time an incentive plan is installed. The installation should pay for itself. In that respect it would be like any new tool purchased for the shop. But to be successful, the incentive plan has to be one that you can "live with." The costs of maintaining the system will be a big factor. The maintenance cost will be much greater than you think, if you agree to carry incentives as far as they should be installed. Naturally, there should be offsetting savings. Progress must continue. When progress stops, the sheriff starts toward our front door.

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[1] "Wage Incentive Plans," Management Consulting Division, War Production Board, October, 1944.

BETTER METHODS

Progress to most of us means better methods. That is what we want to talk about here. We must continue to make progress or we go broke. Ordinarily, we look for better ways to do work. When improvements are made, the standards must be revised in accordance with the changes in work content of the job. In this direction, it is my belief that a good timestudy man can pay his way three times over each year. But he can go further. He can guide management in predicting. He can calculate from time facts what can be expected when certain changes are introduced. He can show the cost reductions to be made by the utilization of wastes caused by delays, extra operations, and rework.

Predicting the effects upon cost is more important than you may realize. You know of many instances where large sums were spent for method improvements without management's having more than a hope that the investment would be profitable. Look how much better it would be to avoid wasting money on some "brain storm."

ESCAPING TIMESTUDY

Benefits such as these are precluded when "rates" are set from past performances. This is obvious because the loosely set "rates" were used to escape the costs of timestudy. But we cannot eat our cake and have it too. Consequently, in escaping the costs of timestudy, we covered up the benefits to be derived from the detailed studies of the jobs. Why we think only of the immediate condition is beyond me. We should know that such "rates" have to be changed at some time, if the plant continues to make progress. We must change or become obsolete. These conflicting points of view lead to the question, "What is your objective in introducing an incentive plan? Is incentive the real objective?" My answer is, "No, the real objective is cost control through work measurement." But I hasten to emphasize that cost control without incentive is of little value.

We need incentives to gain the interests of the employees. People have to be interested in what the incentive plan will give them before the controls can have any real value. I liken the incentive plan to a flywheel. It is this flywheel, going at a steady rate, that makes the management predictions come true. The predictions that are first in importance are in price. We want to make some money on the order when we get it. Next are the predictions of delivery dates, because these are just as important when prices are equal. Then, of course, there are the predictions previously mentioned where we determine the economies of improving the method, tooling the job, or purchasing some new equipment. All these affect the standard costs and cost control.

EMPLOYEE SATISFACTION

The satisfaction of the employee is also based on returns. He is interested in the per cent of earning that he makes under the incentive plan and the opportunity he has to work on incentive. The per cent of return is determined by a number of factors. Here we refer to the design of the incentive plan only. The opportunity is a function of the amount of work covered by incentive. That is called "coverage" in this book and is treated separately. But the employee is interested in another factor that we hear a great deal of nowadays. He is interested in having a fair measure of his skill and ability. He wants to be treated as an individual and given full credit for his contribution. Fair measures of skill and ability contribute greatly to advancement. All of us want to progress. All of us want to get paid for what we do. Getting ahead is the prime objective of most of us.[1] We want to make progress when we are learning a new job. We want to advance upward when we have learned our job.

Another factor in employee satisfaction is what we call fairness. Fairness can be looked at in two ways. One is the per cent return as previously mentioned in connection with the design of the incentive plan. That may be only a number in a formula under certain conditions. To me, a more important measure of fairness has to do with consistency. When standards are consistent, they allow standard time in strict relationship with the work content of the job. They do not include averages for delay time and irregular conditions of the material or equipment. They do not average "the bitter with the sweet."

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[1] Moore, Herbert, "Psychology for Business and Industry," p. 299, McGraw-Hill Book Company, Inc., New York, 1939; Tiffin, Joseph, "Industrial Psychology," pp. 315, 316, Prentice-Hall, Inc., New York, 1946.

And to continue to be fair, the standards must be revised with changes in conditions. But the instant we mention revising standards, somebody says, "Oh, you are talking about 'rate cutting.' That is speed-up." That is an argument, and it has been true in some instances. However, if standards are to be fair, they must be revised upward or downward according to the changes in work content. When they are revised to maintain the relationship between time allowed and work done, they continue to be fair. When these revisions are made from standard data, there are fewer complaints because the changes are made from impersonal recorded data. The advantages of standard data are fully explained in Chap. 5.

Maintaining consistency is exceedingly important as it bears on the satisfaction of the employees. Lack of consistency is one of the great disadvantages that we usually overlook in piecework and similar plans. There was no consistency in past performance to start with. Therefore, how could consistency be gained or maintained in any subsequent revision of the "rates" that were established without sound timestudy?

LOST OPPORTUNITY

Important in employee satisfaction is the "take-home" pay. This can be maximum only when you have full coverage and unrestricted effort. You will remember that full coverage means having everyone on incentive all the time. Partial coverage leads into a whole host of difficulties. The one you hear most about is that the employee has lost the opportunity to earn the accustomed take-home. The fact that he might restrict his production while on incentive is never brought out. But the problem has to be solved. Paying average earnings is a remedy, not a solution.

Average earnings are unfair to the company (consumer) and to the employees who earn their incentive by turning out production. Average earnings increase the cost of output. They are substantially higher in money payments per hour for production that is usually considerably below the standard output. This causes a substantial inflation in the unit cost.

More important, the payment of average earnings is the payment of incentive premiums for non-incentive performance. As such, it is discriminating against those who do perform. It contradicts our everyday formula of "a fair day's pay for a fair day's work." Average earnings are more than a fair day's pay and they are given for an unknown quantity of day's work. The remedy of average earnings is insisted upon at some plants with the statement, "It is management's fault if we cannot work on incentive. Management should be penalized." That point of view is contrary to the whole plan of incentive. It does not conform in any way with"payment by results." It is not related to productivity in any form. That type of thinking drives a wedge between management and employees. It does not consider that both are *employees* working for a living and that the living of both depends upon the profitable operations of the company.

I think we should have more of the attitude expressed in the preamble to an agreement existing in the Pacific Coast Pulp and Paper Industry.[1] This basic clause reads in part as follows:

> The general purpose of this Agreement is, in the mutual interest of the employer and employee, to provide for the operation of the plant (or plants) hereinafter mentioned under methods which will further, to the fullest extent possible the safety, welfare and health of the employees, economy of operation, quality and quantity of output, cleanliness of plant, and protection of property. It is recognized by this Agreement to be the duty of the Company and the employees to cooperate fully, individually and collectively, for the advancement of said conditions.

Certainly words are not deeds. But a basic clause such as the one quoted gives clear evidence of a bringing together as contrasted with the driving apart of the two necessary factors to the success of a business. We need more of that. We need more recognition of the fact that our whole economy depends upon the success of industry. We should remember at all times that industry pays all the bills.

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[1] Crown Zellerbach Corporation and the Pacific Coast Pulp and Paper Industry, Case Study No. 1, "The Causes of Industrial Peace under Collective Bargaining" series, National Planning Association, Washington, D.C.

Arguing about average earnings is looking at the trees and missing the forest completely. If you will grant that it is unfair to those who work on incentive to pay average earnings for non-incentive time, and agree that it is only a remedy, then we can devote our attention to the solution. The only answer that will stand up is more and better timestudy. Full coverage is what is necessary to solve the problem. This can be brought about by better methods of timestudy and standard data worked up in such forms as to allow economical and rapid application of standards.

EXPLAINING THE INCENTIVE PLAN

Getting full coverage is necessary in order to have a sound foundation. Attaining that is only a production problem. Beyond is the dynamic effort that must be made to have success with incentives. Often we hear that the employee says, "It'sall a mystery to me." These comments indicate a lack of understanding of the incentive plan or the timestudy measuring that underlies it. Of course, understanding has two sides to it. One is whether or not we explain the plan. The other side is whether or not some people can understand—or want to.

For example, we know that if a supervisor does not subscribe to the incentive plan, his people will have doubts about it. We have heard it said that "an organization is the lengthened shadow of the man at the top." What the manager believes is often reflected in the organization below him. That holds equally well with incentives, planning, quality control, or any other management device you care to mention.

If we seriously want to gain understanding, then we need to train supervisors, employees, and union stewards in a comprehension of the incentive plan. Of course, it will be difficult to explain the incentive plan if there have been some phony timestudy practices carried on in the past. And explanations may be difficult because the incentive plan uses some complicated formulas. By way of illustration, the following is quoted from *Business Week*, Aug. 14, 1943.

FORMULA DOUBLE-TALK

> Adding friction in many instances are the complicated methods of figuring earnings which characterize many incentive schemes. The

wage formula for operating and maintenance crews in a big steel company's strip mill, for example, is as follows:

Total earnings = $1.2 \times S \times Rb - \$.10A - D \times Rg$ (where Rg exists)
S stands for standard hours earned
Rb for the rate per hour for purposes of calculating the bonus
A for actual hours worked on standard
D for day work hours
Rg for occupational and guaranteed rate per hour

> Imagine the foreman trying to explain to an irate workman who wants to know how come his pay this week is $2.43 less than last week's. Yet the steel company, which wants to remain anonymous simply because it feels that there would be trouble if its employees realized how really involved calculation of their earnings is, insists that the formula can't be simplified without making it unfair.

Explaining is a teaching process. We should plan and carry out an instructional program to remove the mysteries. This need not be done by classroom methods. The procedure is a good one, however, if too much water has already gone under the bridge. Irrespective of methods adopted, it must be remembered that educational work is never finished. We have to repeat the process if for no other reason than that of informing the new people and those who are promoted to new positions. New people must be given the same benefits of understanding that were developed initially. If this is not done, turnover will dilute the understanding to a point where anything can happen. An ounce of prevention should be given in the way of specific explanations at the time the new employee is inducted. A printed explanation included in the employees' handbook will be helpful.

In addition, the foreman should be obligated as a specific part of his responsibilities to again go over the full explanation of the incentive plan. This will improve the understanding by repetition even if no other gain is made. But organizationally, it is necessary that the foreman make certain there are no misunderstandings. This vital step in sound administration is completely overlooked in some organizations, and poorly done in many.

To establish understanding, the timestudy methods have to be made an "open book." There is nothing to hide if everything is done fairly. And fairness is the only basic policy that will work. Fair methods and full explanations create the confidence that is necessary to successful operations. When we can get the shop people to understand the "rules of the game" as well as they know baseball, we will have to get bigger scoreboards.

FOREMAN UNDERSTANDING

In order to have better understanding, it is necessary to make greater progress in supervisory development. Clearly, our past practices have been shamefully inconsiderate. We have taken away the setting of piece rates, one duty that should never have been assigned to a foreman. But when he set "rates" at least he knew what they covered.

Today, in up-to-date plants, the timestudy men have this responsibility. Those who know good timestudy practice talk in a language foreign to the untrained foreman. Those who think they are good, spend most of their time in ivory-tower office techniques and have little left for the shop. So the foreman is out on a limb. He does not understand what the timestudy men are doing, because they don't explain their work. He cannot answer the questions of his men, because he isn't in the know. He cannot operate successfully with the incentive plan, because he lacks the detailed knowledge and understanding of it.

That void must be filled if we are to have successful incentives today. We have to train the foreman in timestudy because, in good organizations, they no longer have the trial-and-error experiences they used to get in "rate setting." The old-fashioned guessing contests are about done for. Those permitted too much favoritism. Too often, they placed the burden of proof on the operator by averaging "the bitter with the sweet." Furthermore, the crude fundamentals that the foreman used to learn the hard way will no longer suffice.

The foremen working with properly set timestudy standards have to know many more details thoroughly. To illustrate, they must know exactly what elements of work are allowed for in the standard. More work done than is necessary makes the standard seem unfair. Besides, the foreman cannot train his people to do the operations correctly without this knowledge. He cannot expect a man to earn the anticipated take-home unless he is at least started with the methods that determined the standard. This reminds me of the biggest single mistake I saw during the Second World War. In only about ten instances that I can remember did foremen ask to see the timestudies so that they could train new people to perform the operations accordingly. One important cause of absenteeism that I never heard mentioned was the promise of 25 per cent extra earnings made by the employment office, and the new people's discovery that they couldn't make it the second or third day.

Furthermore, the foremen have to know that correctly set standards do not include time for delays, setups, and irregular working conditions. Such things were averaged in the "guesstimated" rates. The variations from the average showed up in fluctuating earnings, that is, if restriction had not set in. But, nowadays, progressive managements want to control these interruptions in production. To do so, they must know how expensive they are. Consequently, the modern incentive plans separate all such variations from the operation standards and pay for them as they occur.

It should be apparent, then, that supervision must have thorough training in timestudy and incentive methods to successfully work with present and future conditions. Thorough training can best be given by actual experience, in my opinion. I would select men with leadership qualities from those experienced in the shop and train them to do expertly the timestudy work necessary to extend the incentive plan to get full coverage. When that was done, there would be some cost-minded men ready to do a fine job of supervising departments on incentive.

HIGH-GRADE MEN

Many of these problems of creating satisfaction are properly cared for when management picks out high-grade men for timestudy work—those who have a professional attitude toward their jobs. Good timestudy men would not make the mistake of neglecting to inform the supervisors and union stewards. They would know that the industrial relations problems brought on by timestudy and wage incentives can best be overcome by anticipating them with ample explanations. The explanations would not be technical. Shop folks are not interested in techniques. Explanations of mechanisms are more confusing than helpful.

Nevertheless, all questions must be answered satisfactorily. To do this requires the establishment of definite policies. The rules must be set down. If they are not definite, the explanations will be weak. "Coverup" will be suspected. Then there can be no confidence that the future will be different from the past. Confidence is an essential part of successful incentives. It must be thoroughly established and scrupulously maintained. In this all-important element of success, there is no substitute for fair-minded timestudy men and supervisors.

FACTORS IN SUCCESS

Success with incentives, in any way you may describe it, must begin with the response of people. That means there are degrees of success dependent upon degrees of response. This in turn, grows out of several determinants. The most important, to my way of thinking, is confidence. To a large extent, confidence depends upon the understanding created. Gaining understanding is an educational process. But maintaining understanding and hence confidence requires two elements. The first is fair-minded timestudy men and supervisors. The second is sound and consistent standards providing full coverage. The latter are most constructively obtained when they are based upon standard data. When data is used, many cost-control devices are obtained also, and these are very important to the progressive success of the company. The continuing success of the enterprise is necessary if the incentive plan is to continue. That is obvious. But it may not be so readily apparent that cost controls vital to business success cannot be independent of the incentive plan. Therefore, if we could summarize in one sentence, we might say that successful incentives must provide management with the tools for predicting with practical accuracy and a high level of response that makes the predictions come true.

CHAPTER 3

WHAT ABOUT INDIRECT?

Extending incentives to the jobs and the people not yet measured is a big task. It is well worth the effort, however, as explained in the previous chapters. Now we want to develop some details as they apply more particularly to the indirect people. This will be done because the majority of those left out are in the indirect groups. Remember, however, that the analysis in terms of indirect applies almost entirely to the direct jobs that have been passed by or not yet reached.

Paying everybody the same base wages for a given type of work is wrong. We recognize that fact by using merit raises and rate ranges. The merit raise is the only device available for rewarding differences in quantity and quality of output, when the work is not measured and on incentive. Some method of reward is necessary because all employees are not alike. Some have more skill than others. Some are willing to sacrifice to learn more. Some work more diligently. Such efforts deserve reward. "We must beware of trying to build a society . . . where enterprise gains no reward . . .," says Winston Churchill.

Those with extra skill who want to work should be paid more for their extra efforts. We must have some inducement for those who want to get ahead. We need to provide the means to pull the poor producer up to the level of the good one—not the good one down to the level of the poor. We should do everything we can to encourage those who prefer working to going on relief and accepting support from the State. We should consider the future. The future we should keep in mind is not that of any one individual, not of any one group, but of the United States.

If we recognize that extra efforts should be rewarded, then the question is, "How?" Merit increases are poor means at best. Their use in many plants has degenerated to the point of being practically automatic. True merit is no longer recognized when a contract clause provides that 70 per cent of all those reviewed will receive an increase. Correctly used, they can only partially solve the problem. I agree, however, that merit raises are necessary when there is no other method for rewarding extra output except flat wage rates or salaries. Even then, whatever merit increases are given are based upon opinion. Also, increases are more apt to be given than not because of the attitude of the supervisors toward their fellow employees. So it happens that nearly everybody gets to the top of the range eventually. The usefulness of merit increases is gone. There are no more to give and so the whole process becomes stalemated.

My belief is that people have used rate ranges only because they have not had incentive measures to compensate for differences in applied skill and ability. But the approach is illogical. I recommend the use of the single rate for a job or position class but insist that timestudy incentives are necessary to properly reward extra skill and extra ability.

WAGE DIFFERENTIALS

You say that I am prejudiced. Some go further and say that I think incentive is the cure-all. I like to believe that it is more of a conviction than a prejudice. I have good reasons for insisting that incentive is better than most of the devices I know about. It is consistent with the initiative and ingenuity that built our great Nation. I think we should do everything we can to preserve and encourage the driving forces that brought us where we are. Most important, it seems to me, is the vital necessity for guarding against the drift toward the Welfare State. Uncle Sam cannot look after all of us. Some of us have to work.

These points have a bearing on the decision of whether or not to use incentives. My recommendation is self-evident. Regardless, our interest here is in what to do with the people who do not have extra earning opportunities when part of the plant is already on incentive. The problem arises as a result of discrimination in earning differentials. The discrimination exists because there are people below, beside, and above who are earning incentive. It is present in many progressive companies because they have incentives in part of the plant. A great many have incentives for sales departments and executives of the company. What about the great middle group in between? If incentive is desirable for some, why not for all?

Maybe the direct producers are on incentive while the trucker, sweeper, and craneman who serve them are not. In many plants, the toolmaker and maintenance mechanic are wondering why they ever took the trouble to serve a trades apprenticeship. They are wondering why they earn little if any more than the drill-press operator working on incentive. It is unfortunate that so many use dollars as measures of success. Nevertheless, the mechanic applies the faulty measure and says to himself, "Look at all the time I've wasted." Thus, ambition may be destroyed. Such blockades in the road of progress contradict all our efforts in progressive schools and colleges.

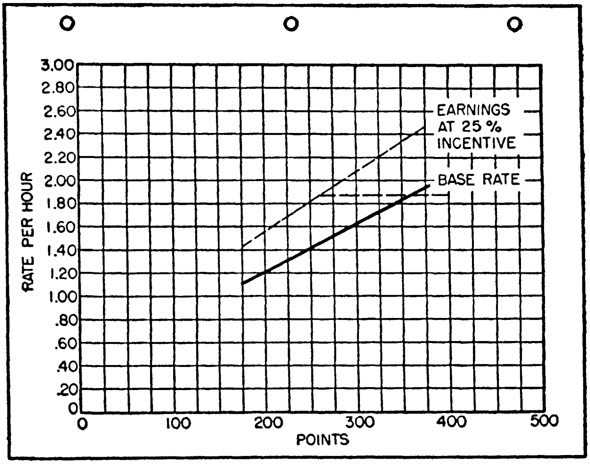

FIG. 1. The cross line shows how those on incentive near the middle range of skill make more money on incentive than nearly all of the higher skilled people who are not yet on incentive.

The factor of discrimination, as I call it, arises under any partial application of incentive. We should be concerned about the groups of people who are not on. The group affected in many plants is the indirect people in both the shop and the office. The magnitude of the problem may be more easily visualized by referring to Fig. 1. The solid line represents the wage line drawn between job evaluation points and representative base wages. The dotted line indicates the expected in incentive earnings of 25 per cent above the base wage. The crossline shows the measure of our discrimination difficulty. It indicates that the operator in a 250-point job class makes more than the skilled people on day rate in all job classes above up to 340 points. The differential of 25 per cent is too big an amount to overcome by any of the usual forms of wage-rate or job evaluation juggling.

CONTRACT DEMANDS

Because your plant was only partially on standards, you may have had to face a demand for an "incentive differential." This is caused by a form of discrimination. Harold Bergen stated the fundamental years ago when he said, "It is not the amount but the difference that causes the trouble." To pay more money is only a remedy. Such a remedy is a very bad choice. It weakens the incentive itself. To emphasize the point, let's illustrate with a problem in second-grade arithmetic. Suppose that the job pays $1.00 an hour. Suppose also that the incentive plan is designed to provide an incentive expectancy of $1.25 in earnings. Now if the $1.00-an-hour man is granted a $.10 sop because he is not on incentive, then his pay is $1.10. As a result, the incentive differential is reduced to $.15 ($1.25 − $1.10). But the percentage is only 13.6. That is not enough, in my opinion. Experience seems to indicate that the minimum percentage should be 20 per cent.

If ten cents an hour can be granted today, who is to deny that a nickel or a dime be added on next year? But, let us look at this situation the other way around. Remembering that this granting of a flat wage increase is a poor remedy at best, suppose that the executives of the company realize that they must make the next step and go to incentives. When true incentives are established, what shall we do with the ten-cent differential? The job-evaluation line has already been thrown out of joint. Shall we pay the incentive premiums on the inflated rate? If we do that, it is unfair to those who were previously on incentive. The alternative is to remove the ten-cent inflation. That is "rate cutting." And, if this step is taken, the incentive inducements to those who formerly received the inflated rate are again only 13.6 per cent. Maybe the only way out is to give the ten-cent increase to those who were on incentive and treated unfairly in the meantime.

THE DESPERATION APPROACH

If I have done a good job of showing the treacheries of the flat wage increase, you may say, "Well, we'd better not try that one." You may give some thought to the problem and say to yourself, "There must be an easy way out of this." Many people have passed this way before and some have come up with the notion that there should be a ratio between direct and indirect. That grows out of the erroneous habit pattern of thinking of overhead as a per cent of direct labor. Because you may jump to the same conclusion, I will do my best to explain the treacheries of this short cut also.

One of the most frequent applications of this incorrect approach is seen in connection with the setup men. Perhaps we see it so frequently because the setup men are about as close to direct as indirect people get. Therefore, the question has been raised frequently and this method used to answer it. For example, suppose you have two or three setup men looking after a group of operators. The setup men work diligently while the operators do nothing. Then when the operators are busy, the setup men have little or nothing to do. It should not be so, but it usually is. To complicate this condition, the relation of work to idleness shifts all over the lot according to the quantities being produced per setup. Obviously, the operator's productivity is not a measure of the setup man's productivity.

In a couple of instances that I happen to know about, the three or four setup men got tired very easily. They asked for a couple more to help them get tired. With the setup men getting help, more finished pieces were put in the operator's tote pan. From this analysis you should be able to see what could happen if an incentive scheme were worked out to pay setup men a percentage of the earnings of their operators. Credit was given to the operator for production that he did not turn out. This added to the inflation of the operator's premium. And of course, the setup man received an inflated premium because he was paid on a percentage of the earnings of the operator. The basis is faulty without full control of relative productivity.[1]

RATIOS ARE NOT MEASURES

But there are other dangers in paying an arbitrary percentage to indirect employees. Such percentages are calculated from the productivity of the direct producers on incentive. Arbitrary calculations are not measurements. To say that one man turns out a fair day's work because another does is fallacious. The producer earns his incentive pay by turning out more than a measured day's work. It does not follow that an indirect man who is paid the same percentage over his regular rate or some fraction thereof is doing the same. And danger lies in the possibility that the producer might very well argue that he would be better off working at some indirect operation for the same relative take-home.

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[1] Carroll, Phil, "Control of Indirect Labor Costs," Production Series No. 159, American Management Association, 1945.

It is easy to fall into these procedures. But they are treacherous. To begin with, there is no assurance of an increase in output commensurate with the greater pay. As a rule, there is not a direct relation between the efforts of indirect and direct employees. In general, the proper ratio of indirect to direct is a changing one, being high at low volumes and low at high volumes.

What can happen with these misleading ratios may be more clearly exemplified if we consider the simple problem of measuring the percentage of scrap. Assume that two types of the same article are manufactured—Product *A*, having normally 10 per cent scrap, and Product *B*, with a normal scrap of 5 per cent. Assume that in a given month the total volume is made up of 70 per cent of Product *A* and 30 per cent of Product *B*. The total average scrap based on number of pieces would be 8.5 per cent. But suppose the total proportions of the business done were changed about. Now 30 per cent of the output is of the kind having a normal of 10 per cent scrap, while 70 per cent has 5 per cent scrap. Then, if the scrap report showed 7.5 per cent, we might be inclined to assume that scrap had declined. It was lower than it had been at 8.5 per cent. But actually the scrap increased, because it should have been only 6.5 per cent. Perhaps this will be more clearly seen in an examination of the arithmetic.

Product	Normal Scrap, per cent	First Period	Second Period
A	10	70% × 10% = 700	30% × 10% = 300
B	5	30% × 5% = 150	70% × 5% = 350
		100 850	100 650%
Standard average scrap......		8.5%	6.5%
Actual current scrap.........		8.5%	7.5%

UNFAIR RATIOS

The unfairness of any ratio of indirect to direct is emphasized by figures taken from the budget of one company. These figures point out that the variable part of the indirect labor account is but 54 per cent of the total expense at the normal volume of production. The remaining 46 per cent is a constant amount that represents indirect work to be done regardless of volume.

Much indirect work is nearly the same regardless of the amount of production. A sweeper does about the same amount of work whether there is much or little output. The setup man gets a machine ready to run for each order regardless of the quantity required. The billing clerk does just about as much typing whether the order calls for a quantity of 100 or 1,000.

It is apparent, then, that a direct ratio to productive labor is unfair to the employees below a certain level of production, and unfair to the company above that level.

WHAT WORK IS DONE?

Another pitfall is that ratio "schemes" do not have any basic record of the work content of the jobs involved. Consequently, there is no logical means for adjusting the incentive payments as the ever-changing methods make it necessary to alter the number of people assigned to the work. Either arbitrary revisions are made, bringing unjustified accusations of "speed-up," or what is worse, payments of unearned premiums are continued. In my opinion, this latter is the more detrimental because the unfairness grows with methods improvements. Eventually, the producers complain about having to work to earn their premiums while others can get as much by loafing. When this stage is reached, the whole setup is in jeopardy.

You can run into the same difficulty from another angle. This comes about because, prior to the establishment of a ratio, the indirect operators were on what is called "daywork." Without incentive, the indirect people were not particularly interested in making the most effective use of their time. Obviously, the number of hours spent in doing the work was excessive. This excess was included in whatever past performance figures may be used in establishing a ratio. The number of hours taken was greater than would have been required if the work had been on direct incentive standards established from timestudy.

It is grossly unfair to those working on direct incentive standards to pay full premium for increases in production over past performances. Such premiums would include payments for the elimination of time that was previously wasted. The wasted time and effort must be excluded from the calculations before incentive premiums are paid.

If you were to use some ratio "scheme," there is no escape for another disadvantage that is more important today than it ever was. These quick and easy solutions invariably are what we call group incentive plans. Even if they temporarily solve the earning problem, they cannot recognize the individual contribution. They can neither measure nor properly reward the individual for the work he does. As a result, you have no measure of individual skill and ability. You have no way of knowing whether the new employee is progressing as he should. All you have to go by is straight seniority.

THE EASY WAY

A lot of difficulties grow out of all quick and easy ways to get incentives. Sure, past performance records and foremen's "guesstimates" were easier than all this highfalutin timestudy stuff. But it should be obvious that the easy ways may bring on more problems than they solve. If people earn what you call "too much money," what are you going to do? Distorted earnings started the 'ratè-cutting' practices some 25 years ago that gave incentives the bad name it is just overcoming. Many shop people still think in those terms. For that reason you may not see the high earnings. You may have restriction of production instead.

But ask yourself the question, "Why have so many concerns changed from Halsey 50-50 to timestudy standards? Why are so many companies getting rid of piecework and using time measurement? Why was 'rate cutting' done so often in years gone by?" This learning the hard way always reminds me of a joke that is so old it has moss all over it. Pat and Mike had treed a wildcat. Not knowing any better, Pat shinnied up the tree to get the cat. Shortly, there was a dreadful commotion up top. Amateur Mike called up, "Pat, do you want me to come up and help you hold him?" "No-o-o," Pat wailed, "Come up and help me turn him loose!"

That is the way some companies feel about their "easy to get" incentive plans. And yet despite all we know, read, and hear, some did it all over again in the Second World War. Many incentive plans were introduced over the week end. Apparently, as the farmer said to the technical book salesman, "I ain't farmin' half as good as I know how now."

COST ANALYSIS DETOUR

Before we continue with some constructive suggestions, you should know another very important reason for measuring indirect work. This one has to do with cost finding. In your plant, probably they figure direct labor and material costs to the fourth decimal place. Then, they spread the overhead on with a shovel. But overhead costs are not proportional either to direct labor or to sales dollars. Past performance figures may belie this statement. If they do, they prove only that the control has been carried on with erroneous measuring sticks. Remember that both direct labor and sales dollars are almost in direct ratio to volume of output.

In contradistinction, overhead costs—particularly those of overhead labor—are not proportional to output because of the substantial fixed expenses included. This might be described as the cost of the nucleus of the organization. This setup element is incurred chiefly in indirect labor cost and may approximate 20 per cent of the total cost of business at normal volumes. Such amounts are too large to be overlooked. Besides, there are several degrees of overhead present in the usual industrial operation. These are caused by the several products manufactured and sold. Each will have a greater or less than average cost of overhead. For instance, the indirect labor costs of engineering, selling, timestudy, accounting—to mention a few—will differ for each of the several products turned out.

Correctly, then, each product has its own indirect labor cost. Any shifting in the proportions of the several products, therefore, will distort any overhead ratios that might be computed. For example, a ratio would be misleading if the total output were to remain the same when there was an increase in the proportion of specially engineered products. If such a ratio were based on sales dollars, it would be further distorted where the engineered product carried a lower margin of profit.

That is not all. We must consider these basic facts in the light of a further compounding force. The overhead is rising automatically as a result of improvements in manufacturing methods. This shows up as an increase, even though it may involve only a transfer of charges from direct to indirect labor cost. The tendency persists as we continue to introduce better manufacturing methods, improved equipment, tools, and designs, and even cost controls. It has an important influence on the rise of indirect labor costs, wholly aside from the declines in total cost that these improvements produce. It enlarges the possibility of errors in allocating overhead costs.

To get overhead labor costs charged more correctly, I recommend measurements and job standards. These, with counts of output, make it possible to charge costs directly to the overheads of the products that cause them. So far as this can be done, the overhead cost errors are reduced. This by-product of indirect measurement is much more important than we think. Its value will increase as competition becomes more severe.

LIMITED THINKING

Standards for indirect labor are only part of the answer. I recommend the next step—incentives. And as you have noted earlier in this chapter, when incentives are used in part of the plant they should be provided throughout. Why our thinking seems to have stopped at the line that divides direct from indirect labor, I do not know. It is this same incomplete thinking that has given rise to the two divisions of job evaluation. We think of job evaluation as a basis for hourly paid people but contemplate a wholly different setup when consideration is given to position or salary evaluation. Actually, there can be little or no distinction made between these two groups over the wide range of overlap. That would have to be considered if the methods of paying wages were the same for both.

We should not make the same mistake in thinking about the field of good industrial engineering. It can be made as effective in the overhead labor measurements as it has been in what we have called "direct operations." We can make method studies of indirect operations that will be even more effective than those made of the direct labor operations. We can institute and make effective the basic principles of a good suggestion system. For some unaccountable reason, suggestions seem to be sought almost entirely for the improvement of direct manufacturing operations. One of the very first places to work is in that huge field we cover with the word "system." The systems that we have devised for the conduct of business operations involve multitudinous copies of paper work, tags, cards, and what not. And my concern is not for the cost of the paper. Ben Graham of Standard Register keeps telling us, "The cost of handling the paper ranges anywhere from ten to forty-five times the cost of the paper."

These systems are not cures but remedies. They are devised to help us avoid thinking and to overcome the shortcomings of ordinary mortals. The number and the intricacy of the systems are multiplied by the individualities of the department heads. They generally have a free rein to exercise their creative abilities. The result is that many department heads work the isolation principle to the ultimate. They seek to make their bailiwicks completely self-contained. Naturally, the duplications are multiple. The cost of indirect is much higher than it should be. This illustration is mentioned to point out what we have been overlooking. If we are really serious about the cost of overhead, we need to spend as much energy in the study of indirect labor operations as we have repeatedly given to the measurement of operations carried on in the shop.

DIRECT MEASUREMENT

You may be one who asks the question, "Do you believe it is practical to place all operations on wage incentive?" The answer is "No." What is practical is based on the relationship between the cost and the return. The return depends upon the conditions that affect the work being performed. The cost is related to the methods used in timing and setting standards. This is not dodging the question. My experience clearly indicates that most concerns can extend incentives a great deal further than they have, and with fair returns. In this consideration, we cannot limit our thinking to the costs of timestudies only. We must include the costs of what can and does happen if we fail to do the timestudy work.

Direct incentives are the most satisfactory. They pay according to measured output. The measurements of work done should be made by timestudy. Then the output can be gauged in terms of standard times. Such measurements are most effective from the standpoint of control because they can be utilized to bring about a constant cost per unit of output. The attainment of a constant cost is practical perfection from the standpoint of control.

The stabilized costs are the outcome of the application of two basic principles of direct incentive. One principle is that increased earnings are desirable to the normal employee. The result is that direct incentive is usually effective in raising "take-home" earnings. Second, good incentive based on fair timestudy measurement pays a 100 per cent premium for production turned out in excess of standard requirements. It follows, then, that when these two conditions are present, the cost per unit of indirect labor output is practically constant for all performances above standard.

CONTROL THE QUANTITY

Of course, this constant cost per unit is of the indirect labor operation. It is not necessarily constant for one unit of salable finished product. This should be clearly understood. It is readily seen in such operations as billing, janitor work, setup, and maintenance. To explain a little further, we might assume the standard time for making out an invoice to be three minutes. Such a standard might not change at all if the customer ordered 10 units of product instead of 1,000. Consequently a billing clerk on incentive might be earning premium and, as a result, the cost per invoice might be at standard. Yet the invoicing expense might be several times more per unit of finished product under one volume than under another.

Similarly, many indirect labor operations are related, not to the volume of product made and sold, but to the amount of work required in carrying out the indirect function. Therefore, care must be exercised in measuring indirect operations to make certain that standards are established in terms of fair work requirement of the operation itself. At the same time, it is necessary to set up also the means for controlling the repetition of the work.

To illustrate, in the shop we pay incentive for good pieces finished. Doing work over again is clearly repair. And the distinction between the two is easily made. However, many indirect operations can be repeated at long or short time intervals. Take window cleaning, for example. The windows can be washed once a month or once a year. The standard time would be about the same for either job. Probably the window cleaner would make premium under either schedule. The cost to clean windows would be constant per time. Inspection is another example. The inspector may have a standard time of 2 minutes per piece for checking gears. He may be working along at above normal pace and earning satisfactory premium. But—he may be inspecting every gear when it would be sufficient to inspect one in ten.

The illustrations are intended to indicate the need for controls beyond the measures of the indirect labor jobs. The controls must hold the occurrence of work done to some set normal. Otherwise, the indirect labor costs may continue high, perhaps increase, even though the work is performed efficiently on correct incentive standards.

LACK OF SPECIFICATIONS

From what has been discussed, I hope you see good reasons why indirect should be measured. Next we want to tackle one of the major stumbling blocks. It gets in our road because we have not analyzed the problem. We have shied away from measuring indirect because we say, "It can't be done." Surely you remember the saying from the War that goes something like "The difficult will be done immediately—the impossible takes a little longer!" Well, actually our problem is that we are looking at the indirect from too close up. Might you not say "impossible" if you were to look at some of your production methods from a viewpoint of 25 years ago? And you hasten to ask, "Where does the twenty-five years come in?" That is just my way of emphasizing how far behind the times we are in the measurement of indirect.

As a matter of fact, we are further behind than that. Many concerns had good incentive installations longer ago than 25 years. Nevertheless, the intervening time has been spent almost entirely on perfecting the measurement of direct labor operations. The indirect has been almost completely neglected. In the meantime, we have introduced better engineering, better tooling, better planning, quality control, inspection, gauging, and numerous other devices to help repetitive operations. Rarely have any of these devices been used to help indirect operations.

The one that is most conspicuous by its absence is engineering. There are almost no specifications. By way of illustration, I might relate part of a conversation that was interesting to me. I was riding home with the foreman of a pattern shop. Out of the blue he asked me the point-blank question, "Do you know of any pattern shop that is on incentive?" His intention was to establish proof that it could not be done because it had not been done. My cue was to answer his question with a series of questions that would enable him to reach the correct conclusion. First, I asked him how he would go about getting a pattern made. He began by saying that he would give a man the instructions, a drawing of the part, and authority to proceed. Then he went on with a number of details and finally came up with the answer that the men would complete it according to his, the patternmaker's, ideas. Then I asked if he would get the same results if he gave the job to a different man. He admitted that the end results would be different. One man might finish the job and have ten core boxes, another might have seven or twelve. The whole point was that each man would use his individual artistic tendencies and create what he thought was the right result.

If our automobiles were built in this way, we could not afford to ride in them. Even if we could afford to pay for them, we could not purchase the spare parts in case the cars broke down. If we go out to buy an automobile tire, a lamp socket, or a ⅝-inch machine screw we expect it to fit. The only reason it does fit is because it is made to specifications.

So the answer to the patternmaker foreman's question was that the measurement of patternmaking would be difficult because each man's methods and procedures were different. There were no specifications. There were no designs. Then I said to him, "Suppose you chose two of your better patternmakers and asked them to design what was to be made. Then, if you turned the design over to any one of your better men, wouldn't each one build the pattern in much the same way?" He began to see that the problem was not with timestudy as much as it was with lack of engineering.

SUPERVISORY PLANNING

A similar obstacle to be overcome in applying incentives to indirect is often the lack of another type of engineering. It isn't so much the going back for tools, as we so often remark jokingly. It is the cut-and-try approach to the work itself. The condition is a greatly exaggerated example of half-done engineering such as we see in the job shops. Every mechanic is expected to figure out his own way to do the job. Supervision is almost non-existent from the standpoint of work planning. The presence and amount of this vast waste is developed through timestudy. It cannot be revealed and evaluated as definitely or as cheaply by any other means.

One amusing incident will illustrate the point. The maintenance supervisor received a hurry-up phone call to send someone to fix the leaky roof. He dispatched two carpenters. After considerable time they returned to report that the roof was made of concrete. So the supervisor sent some other men. Even then he did not go out and take a look at the job himself. If he or some assistant had gone first, he would have learned enough about the job to know what men, what materials, and what tools were needed to make the necessary repairs.

I will use a story to illustrate another waste that is quite prevalent in many indirect operations. Some time ago, I was talking with a man who proposed to put a helper on a job at $.89 an hour as a substitute for a high-priced man who had been doing a helper's work. The problem had to do with balancing the operation. Balancing teamwork is difficult because the helper cannot take over a mechanic's work in order to equalize the two parts of the job.

So my question was, "If you put the helper in place of the mechanic, how much of the cycle will he have to wait for the mechanic? What per cent of the time can he work productively?" The answer was, "He'll wait about thirty per cent of the time, and work about seventy per cent." Now, the arithmetic is that an $.89 helper working 70 per cent of the time would cost $1.27 for an hour of production. That cost was more than the $1.14 being paid to the mechanic before the change. So the question is not the amount per hour but the productivity per dollar. Frequently, we make real progress by hiring skills at higher rates because the net cost comes down through better utilization of time.

Our planning on production operations is way above the average of that done on maintenance and other indirect operations. About the only controls we seem to have for indirect are two. Both are the pressure type. One is the pressure by the production departments to get the service they need to keep production moving. That tends to bring about a certain degree of efficient performance. On the other hand, there is the pressure from management to hold down ratios of indirect to direct and to hold down the dollar amounts.

[1] Carroll, Phil, "Cost Reduction," p. 12, Bigelow-Sanford Berkshire Conference Proceedings, October 18, 1947.

[2] Carroll, Phil, Incentives Must Be Worth Effort, *Manufacturing & Industrial Engineering*, p. 15, October, 1948.

SUPERVISION PREMIUM

Before concluding a discussion on the general approach to measurement and incentive for indirect, it seems important to emphasize one particular group that should be put on a really effective incentive—namely, the supervisors. The supervisors are the ones most likely to make or to break whatever plan of incentive is established. Certainly it should be made very much worth their while to direct the control of their own costs.

A good incentive plan for supervisors should be based on at least two factors, namely, payroll cost and incentive performance. Certainly there can be no fixed formula of relative weights to be given these two factors. In general, however, it is suggested that the weighting might be approximately 35 per cent for employee performance and 65 per cent for cost control. The factor of cost control should not consider anything that is not wholly controllable by the supervisor. No such items as light, depreciation, or any allocated cost should be included in the basis for determining supervisory premiums.

Such things as tools and materials should be considered only in terms of the variation from normal amount, generally speaking. For example, scrap can be a factor but the material cost as a whole should not. Excess tool cost can be included, but not the basic tools themselves. The reasons for these distinctions should be apparent. The supervisor does not control the costs of the basic materials and the tools used. Both are often exactly specified by the product engineers. To include the relatively large amounts of basic costs would give the items such heavy weighting that it would almost completely destroy the sensitivity of the measurement of controllable variations.

LOTS OF HARD WORK

After considering what has gone before, your comment may be the same as that of a manager I know. After I had explained what was required for success with sound incentives he said, "But Phil, that takes a lot of hard work." My reply was, "Do you know any easy way to make half a million dollars?" He quickly said, "There's none I know of."

Later on, I want to bring out some methods that make the job somewhat easier. But there is no easy way. Too many look for it. Some find what they think are simple solutions to the complicated problems of incentive. My opinion is that there can be no simple solution that is fair.

These methods are by no means new. They have been used for years, and applied to a variety of indirect operations that would make a list as long as your arm. Numerous types of shop and office indirect operations easily lend themselves to direct measurement. However, like any other production tool, good incentives cost money. The better they are, the more they cost. But do not make the mistake of assuming that high cost is a correct index of good quality. Investments made in sound timestudy-wage incentives are no different from anything else worth while. And experience has shown that there are many elements of business expansion for which managements spend more time and money without gaining nearly as profitable a return.

Through sound incentives, there are higher take-home wages, lower costs, and increased productions to be gained. These benefits are not obtainable by any other means now available for as small an investment of time and money. You should look squarely at the facts. You should give more serious attention to the extension of sound timestudy-wage incentives because it is good business to do so. You should be as soundly practical in this field as in other parts of business administration.

CHAPTER 4

DOES TIMESTUDY COST TOO MUCH?

"How many timestudy men should there be per one hundred employees?" The question is thrown at me so often during discussion periods that I have a pet answer for it. "Whatever the number, double it!"[1]

In the first place, a studied answer to the question would involve at least six major factors. They are listed here as conditions:

1. Are we dealing with (*a*) installation of incentive or
   (*b*) its maintenance?
2. Are the operations (*c*) jobbing or
   (*d*) repetitive?
3. Is the company (*e*) a progressive outfit or
   (*f*) one that is dying?

All these influence the number of standards and their rate of change. Please take note, because all the statistics on timestudy man ratios I have seen are completely misleading.

Besides, my short answer to the question is not a silly one either, if we want to think in terms of cash money. One company paid out the equivalent of the salaries of eight timestudy men, but in the form of 6 cents per hour to those not on incentive. And remember, there were no timestudies being obtained for this expense. Another company was faced with a cost equal to that of forty timestudy men through a demand of 10 cents per hour for indirect employees not on incentive. Here again, no solution would have been obtained even though the equivalent money had been spent.[2]

These two illustrations are among the many we know about where substantial expenses are incurred by default. They are penalties. They are dollars that should have been spent for timestudies. Had the timestudy work been done in time, the compromises might not have been made. You throw up your hands in holy terror and say, "But increasing the number of timestudy men adds to our overhead. It is already too high!"

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[1] Carroll, Phil, Higher Productivity through Wage Incentive, *Modern Management*, Vol. vii, No. 3, p. 26, April, 1947.

[2] Carroll, Phil, Successful Incentive Administration, *Modern Management*, Vol. viii, No. 5, p. 34, July, 1948.

Timestudy is an overhead expense. It is scrutinized because it shows up as so many names on the payroll. The tangible returns for the money spent are not obvious because we timestudy men do not report them. We assume our work is sufficiently productive to stand on its own feet. Meanwhile, management holds the crew of timestudy men to a minimum. At the same time, I must admit that some of these timestudy men would not know how to proceed with the measurement of jobbing and indirect operations if you instructed them to do so.

FULL COVERAGE

Regardless of individual capabilities, we have a big problem to solve. We have to apply incentive to all work once the principle is adopted as a policy in the plant. Incentive opportunity must be provided for all employees, both direct and indirect. Full coverage is exceedingly important because the successful incentive plan enables those willing and qualified to earn about 25 per cent more money than the base rate. Such an amount upsets wage differentials. Lower skilled people on incentive make as much or more money than mechanics and supervisors on straight time wages. Industrial relations problems are created that no amount of bargaining or wage-rate juggling can overcome. The amount of money involved is too big a factor. The answer lies in more and better timestudy. More timestudy has been suggested in the "double the number"! But we cannot close our eyes as we did during the war and load on more man power. They would get in everybody's hair. Besides, we have to keep our own skirts clean by using methods at least as efficient as we expect in those operations we measure.

STANDARDIZING CONDITIONS

So let's look at some of the details in the timestudy process to see if we can find reasons why certain managements say, "Timestudy costs too much!" The first point that we come to is a stumbling block to many men. Starting with F. W. Taylor, there have been two schools of procedure. F. W. Taylor urged that all the conditions should be perfected before timestudies were undertaken and work standards set. On the other hand, Henry L. Gantt, one of his disciples, advocated that an attempt should be made to make the most of conditions as they existed.[1]

Perhaps it is the repetition of Mr. Taylor's ideas in the texts that induces so many of us to attempt perfection before setting the standard. That seems to me to be one of the chief causes for delay and expense in timestudy operations. I have no fault to find with "perfecting the job." As our friend Don Copell puts it, "Our best is none too good." We can and should do much more than we have done toward improving our methods. But I insist upon making the point that if we fail to get coverage because the methods are not perfected, then we have made the wrong choice of the two possible.

Perfecting the method is not always practical if we remember that any change is but one of a long series of similar improvements. You all realize that once a gadget is made for a particular operation, it immediately becomes obsolete because we all suggest other improvements to be added. This happens for two reasons. First, some of us cannot visualize changes until we see the new tool or apparatus. Second, some of us can improve only—we cannot create. Most things we have today are but improvements of former devices. If the changes made today are but a part of the total possible improvements in the future, is it reasonable to attempt to gain perfection before the first standard is set? Is it not much more practical to make the obvious changes and set a standard to fit the conditions in order to more quickly obtain the advantages of incentive for both the employee and the company (consumer)?

METHOD CHANGES

Perhaps it is the wish to avoid changing a standard once it has been set, or the inability to properly rate performance, that induces some timestudy men to seek perfection in the operation methods. If the timestudy men and the management want to avoid changes in standards, how are they going to maintain measurement in relation to work through future changes in process? Changes are sure to occur. The great number of possible changes that may come make it seem impractical to attempt to foresee them all prior to setting the standards. Such a process requires more than expert timestudy effort and not a little of crystal gazing.

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[1] Alford, "Henry Laurence Gantt," p. 130, American Society of Mechanical Engineers

Now approaching the question from the other side, remember that I am prejudiced because most of my experience has been in the job shop. Frequently, tailor-made articles are turned out by what I call cold-chisel methods. Many of these plants do not have such things as automatic screw machines. They would have no use for them. You raise your eyebrows and ask, "What bearing has that on my problem?" The fact is that methods are related to quantities. But it means also that standards have to be set on methods that are less than perfect.

SOME ARITHMETIC

You must consider the costs of methods improvement. Better methods must pay for themselves, we all agree. But do we agree as to the method of figuring savings? Let's use some arithmetic.

Suppose you look at an operation costing $10.00 and see ways of improving it that would reduce its cost to $6.00. The saving anticipated is $4.00. But the operation was on "daywork" all during the time we figured out the new method and got it to work properly. All the advantages of incentive were lost. Some companies may even have paid "average earnings" for the total time the job was not on standard.

Now, let's figure it the other way. We could anticipate certain savings from putting the job on incentive. Let us assume for ease of figuring that the saving would be $4.00 through this change. The same reduction would bring the cost down to $6.00 on incentive. But notice. If the saving expected from method improvement is still 40 per cent, the amount now is only $2.40 ($6.00 × 40 per cent). The question then is, "Can we pay for the methods improvement on the basis of a $2.40 saving?" Be careful. It takes a 67 per cent greater volume per year of production to pay for the improvement. So much for the arithmetic.

You fully realize that the amount of cost reduction to be made by the installation of either incentives or method improvements can be anything according to circumstance. But I am trying to emphasize two factors here. The first has to do with the arithmetic. Ask yourself the question, "Can I pay for the methods improvements after the incentive is installed?" And then remember that full incentive opportunity for all employees is what we are emphasizing in this book.

CONTINUING CHANGES

Methods improvements have to be made continuously. Many will be made after the job is "perfected," if that is the philosophy used. If that fact is conceded, then why not take the long-range point of view and get the work on incentive before trying to attain perfection in methods? The attitude of mind has an important bearing on the coverage by incentive. Unfortunately, the philosophy does not work out the way it is supposed to. In my personal experiences, there have been a number of instances where the coverage of direct labor operations *only* did not exceed 35 per cent after years of timestudy effort. The perfecting attitude was so pronounced in the minds of the timestudy men that they spent most of their time going over the jobs that were already on standard. They seemed never to get around to applying standards to the remainder of the operations.

COSTS BEYOND TIMESTUDY

But costs due to delays and loss of incentive are not the only considerations. There are several other reasons why we should carefully think out the approach. Without timestudy facts, the selling of proposed changes must be done largely on the basis of opinion. The opinions of the timestudy men are pitted against the "it can't be done's" of factory supervision. This process takes much more time than many of us realize.

In addition, there are the costs of bad judgments. Won't you recognize that a number of so-called improvements are failures in that they do not save their cost in a year's time? A year's time is a practical limit because progress is so rapid that other improvements will make the good ideas of today obsolete in that time. When the standards are set, or at least when the timestudy information is available, factual determinations can be made as to the economies of the proposal. Certain suggestions may not be put into effect because they will not pay for themselves.

SUGGESTED WAY OUT

You may well wonder what, if anything, is done about standardizing conditions under a different approach. Certainly methods must be considered. Changes are of two general types. One requires capital expenditures. The other involves simply re-arrangements of the work elements. An efficient way to handle those involving capital expenditures is to prepare a list of such changes for management to study. This list should show the standards required for doing the operations both ways, with the indicated savings in time. You can extend the saving per operation by probable future quantities and convert into dollars. Some one skilled in such matters can estimate the cost of the equipment needed to make the changes. Comparing these will make it self-evident whether or not the suggestions are profitable. Management can then decide which ones will be adopted, and when. Some suggestions may be very fine but not profitable at present quantities. Others, while profitable, may require sums of money larger than the firm can spare at the time. Whatever the decisions may be, the timestudy measurement can go on toward completion while they are being reached.

I was trained originally to "first get the methods right." In one instance, it took me 9 months to complete standard data for cylindrical grinding. Probably I was unskilled and wasted a lot of time. But the process took several times as long as it should have, if measurement had been undertaken without first getting everything in order. Looking back, I believe the same results could have been gathered in 6 weeks by a man skilled in building standard data.

SELECTING THE OPERATOR

The next point that many dwell upon is that of selecting the operator to be timed. If analyzed, this seems to be a defense mechanism. The operator is selected because of the sequence of motions used or the rate of speed in performance or some combination of these two. Now, a skilled timestudy man who is accustomed to timing miscellaneous operations just as they come, and who can rate performances as he sees them, is not concerned with selecting the operator to be studied. In many instances, selection is not possible because there is only one operator doing a given type of work. While it is true that a good operator who repeats the same sequence every time is easier to study, that is just a convenient circumstance.

Looked at from another standpoint, there is a very good reason for not selecting one of several operators even when such procedure is possible. It seems a lot more practical to time them all. In preparing standard data, it may be necessary to time them all in order to get the complete range of information necessary. But there is another reason that is more important. My experiences prove to me that more time is spent in explaining to John Jones and Susie Smith why they were not selected for timestudy than would have been used to time them.

One costly part of this step is the waiting time. Waiting occurs because the person we might select is not available to do the operation we plan to study or is not working on some operation that is to be timed. More costly, in my opinion, are the ill wills created. How would you like to be asked to move over so that your fellow employee could be studied? Would you resent it? Naturally. You would have been turned down. Besides, you would say later, "The standard isn't fair—Joe is the best man in the shop. No one can meet a standard set on him." These may seem like trifles to you. But think back. Would the coverage be greater if you had taken a representative number of studies on everybody, and built them into data?

WATCH READING

Here is another trifle we should consider. Much coverage has been lost because of the hours wasted in subtracting watch readings. Most of the arguments in favor of the continuous watch reading hinge upon the matter of accuracy. Accuracy is spoken of in two particulars. One has to do with the recorded time. The other concerns an attempt to insure that the timestudy man puts down everything that takes place. The continuous watch readings may include all time within the study. It affords no guarantee. Still there is no assurance that irregularities arising in the studies have not been added in with some other readings. Such laziness will create abnormal times that may be completely disregarded in the analysis. They should be disregarded as times for the elements as recorded. These times apply to elements different from those described. The irregularities themselves ought to be measured. Insistence upon continuous readings as a solution to laziness should be called defense reasoning. A timestudy man who will leave out a part of the study for his own convenience cannot be controlled by a "system." He is mentally dishonest. As Ralph Presgrave puts it, "If timestudy is to be carried out by unobservant and unimaginative hirelings, then perhaps the continuous method would be better."[1]

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[1] "The Dynamics of Timestudy," 2d ed., p. 42, McGraw-Hill Book Company, Inc., New York, 1945.

There is a small error incurred in the use of snapback reading. This error is inconsequential in comparison with three other errors in the "rate-setting" timestudy. Most people gloss over these without even batting an eye. The first is the possible mistake in rating the performance pace. The second is variation in amount of relaxation factor added. The third, and probably the greatest, is the divergence in methods determined as standard for an individual operation. Any errors made are carried over into "rates" set from individual timestudies. Such inconsistencies should be avoided by using standard data compiled from many studies.

The continuous watch reading is too costly, whatever its merits. It takes a lot of time to subtract readings before element times are obtained. This is all added cost as compared with the snapback method wherein element times are recorded directly. But we should recognize that a greater disadvantage exists in the huge loss of time spent at the desk in "ivory-tower" indirect. The timestudy men are not in the shop where they could be doing productive work. Further, as Ralph Presgrave says, the observer may be "flying blind." He can be recording figures in the continuous semi-automatic fashion without seeing the operation. Certainly, he cannot know what changes are taking place in actual times.

CLERICAL METHODS

Those who favor the continuous method offer two suggestions to reduce the wasteful subtraction procedure. Some say that clerical help should be provided to subtract the timestudy readings. This may be one way to reduce the loss of timestudy time. But much of the cost would still be there. I have yet to see this procedure in operation. Others suggest that the timestudy man subtract the study while it is in progress. Considering only the cost of subtraction afterwards, that is a way out. However, such a short cut is not practical. The timestudy man is using his skill and attention in a clerical effort while he is supposed to be observing what is taking place during the timestudy. His analytical mind is miles away from his work. To all intents and purposes, he might just as well be daydreaming. Surely, he cannot take a study, as distinguished from a tally, if he is subtracting as he goes. How could a timestudy man take the detailed breakdown required for data preparation while subtracting continuous readings? Obviously, he can't "see" what is going on. And many of the elements required for sound data analysis are too short to allow time for subtracting.

In contrast, the timestudy man using the snapback method can concentrate on the operation that is going on before him and record actual times. He can tell when the operator's pace changes. His analysis of what is being done that causes time variations is what enables him to establish the proper element standards. This is the important consideration in watch reading. This analytical observation is lost in the continuous reading method. The results aren't known until afterwards.

SELECTING THE ELEMENT STANDARDS

Irrespective of the type of watch reading, some procedure must be used to select a representative time from the several recorded. Thirty years ago, a formula was used to obtain the mode. Since then, some timestudy men have worked out an arithmetic average. Others straddle these two methods by recapping all readings obtained in their order of magnitude, with occurrences. The reading that occurs the most frequently is the one usually selected. This median is very close to average. But more judgment can be used in a selection than enters into an average. Unrealistically, many who use these mathematical devices proceed on the premise that the figures obtained are normal times. This is a grave mistake. The average of a 30 Units per Hour (50 per cent) performance time is twice as much as should be allowed. On excellent performance, the average of the times taken at 90 Units per Hour (150 per cent) rating are only 67 per cent ($^{60}/_{90}$ or $^{100}/_{150}$) of a fair standard.

SELECT IN TIMESTUDY

Probably, you know that rating is necessary to correct actual times recorded to normal times. Rating must take place while the study is in progress. Only the individual who takes the timestudy is in a position to make the rating. This is facilitated by the snapback watch reading method. The timestudy man can concentrate on the relation between the performance he sees and the times recorded for it.

Some advocate that each reading should be rated. In theory that is entirely correct. Practically, however, it cannot often be done. When finely detailed studies are being made for standard data purposes, the reasons are obvious. If a timestudy is broken down into elements of .05 minute and less, there is not sufficient time to observe what is going on, read the watch, record the time, and also make a rating. There are practical ways, however, to accomplish almost the same result. One method is to apply an over-all rating to the timestudy and then to note the specific readings that conform to that rating. I use a circle. We have digressed into the field of rating here to make a point on cost reduction in timestudy and, in addition, to indicate two added advantages of the method described:

1. The readings circled are more correctly rated than an average could be.
2. The time of selecting the reading to use has been completely eliminated.

Because both take place during the timestudy, these advantages are gained without adding to the cost. Also, the circling decisions add to rather than detract from the concentration of the timestudy man on his primary object.

APPLYING RELAXATION

Next in our process of timestudy cost analysis is the method of applying relax factors. A common method you may have seen is the one that applies all relax as one figure at the end of the timestudy. This method is not used when the timestudies are prepared for standard data. The studies for data are not totaled, as a rule. In standard data, every element is analyzed with respect to others of its kind. They are disassociated from the timestudies of operations. Therefore, relaxation is applied to each individual element.

But for those who insist upon using the individual timestudy for "rate-setting" purposes, it should be explained that applying relax to the total is probably more costly over-all than would at first appear true. While there is an apparent saving in applying relaxation only once at the end of the study, this must be repeated again and again every time some elements in the study are altered. But there is another reason for not doing it. The sum of the elements including relaxation will be different from a total plus a total relaxation. This happens because of the rule of thumb "five or over goes up."

CONFUSING EXPLANATIONS

This question of how to apply the relax factor is much more than a detail. When explaining a change in standard to the operator, it is a lot better to have the relaxation added into each element. When several elements are eliminated, those can be crossed out and a new sum taken. This will equal the old standard less the sum of the elements eliminated. Not so, with the other method. In the first place, the old standard must be reduced more than the sum of the element times shown. Second, the necessary end juggling of total relax, with the probability of differences previously mentioned, looks like sleight of hand to the operator. He is not accustomed to percentages. He thinks he is being "gypped." And here is where the time is lost.

You realize, of course, that we are heading down the one road toward standard data. In that process, the addition of relax could be omitted until final normal values were determined for constants and variables. That would be a further saving. I do not recommend this method, however. Relax could be forgotten. Anyhow, my personal preference is to always work with element standards.

Right here is another saving. When applying relax to each element, do you record the calculation? You should omit it. Cross out the column on the timestudy form placed there for the extra, unnecessary figures. You can apply the rating and relax in one slide-rule step. Then, set down only the final result. The relax factor to be applied should be specified in the timestudy *manual.* Why write it or its amount on the timestudy?

ELEMENT DESCRIPTION

In the next step, I am sure you would not do what I did for years. It was such a waste of time. But we had a nice big timestudy form. To be sure, there was only a little space for recording a study. About 18 elements and 10 cycles were all we could record. You have seen such forms. Examine yours to see if there is sufficient room for the study. But the back of ours had nice lines for copying the element descriptions over from the front. The procedure gave me lots of practice in hand lettering. While practicing, I was not producing timestudy results.

Why not set the element standards right next to the element description? You can use a colored pencil to distinguish them. Then they are already for transfer to the Comparison Sheet. All the rewriting time is saved.

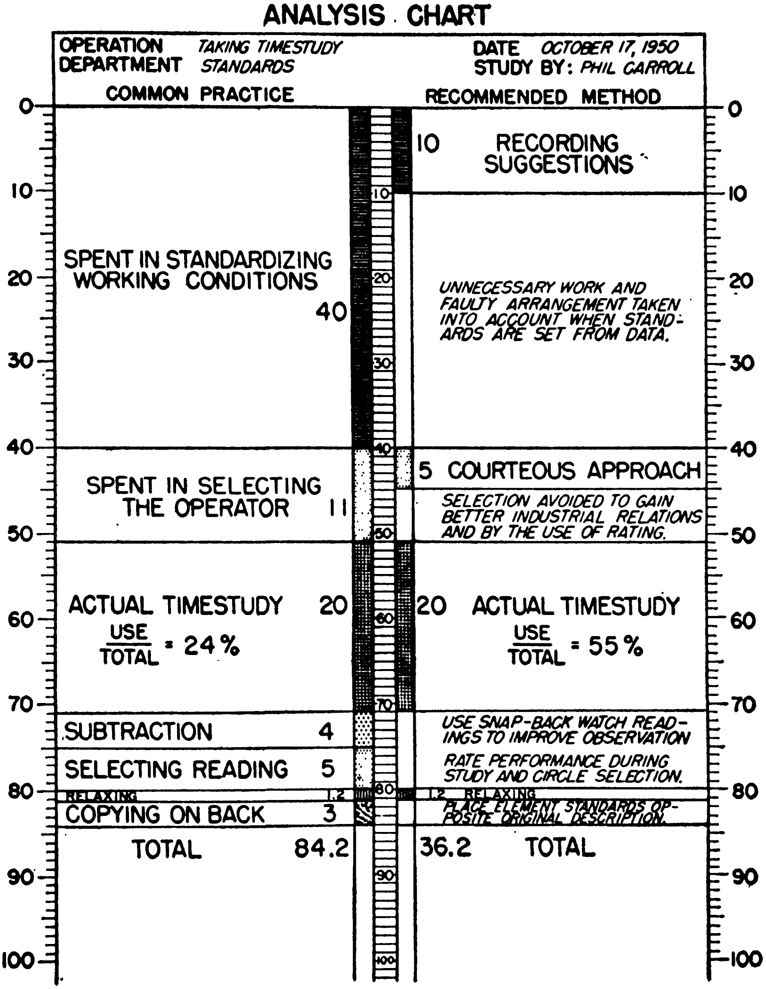

Fig. 2.

COMPARING METHODS

The time savings we have discussed are shown pictorially on the accompanying chart, Fig. 2. It was worked up for a talk entitled "Practical Timestudy." Some of the figures had to be picked out of a hat. But the 84 minutes was an average time taken from a test of over five hundred timestudies by men using "rate-setting" methods. These studies were taken in a plant doing typical machine and foundry operations.

Any such chart you might work would differ in some details. Even so, the important considerations are two:

1. How much time can you save in unproductive clerical steps?
2. How much can you increase the *use* part of timestudy effort?

Nothing said here is to be misinterpreted as short-circuiting. Anyone can rush out, clock a few pieces, and hurry back. What I am looking toward is better timestudy in its full meaning, but stripped of the waste motions. My objective is the same as we all strive for in any shop operation. And all this is part of my effort to show that the costs of full coverage need not be x times the present cost per employee on incentive.

ACCOUNTING APPROACH

To shift scenes for a moment, there is another device that cuts into total coverage. It is an outgrowth of some accounting approach. This shows up where the timestudy department confines its efforts to the measurement of direct labor operations only. It is laziness or faulty thinking when a timestudy man moves some part of the productive work over to a supply man or a trucker or a setup man in order to ease the problem of measurement. Throwing the difficult work into overhead does not solve the problem. Shifting the work is no solution when you plan, as you should, to put everybody on incentive. Actually, it creates more problems of discrimination in earning opportunity.

Frequently, the accounting is all mixed up in that only operations that can be measured for incentive are classed as direct. All others are classified as overhead. Casting cleaning in the foundry is a common illustration. Inspection, painting, boxing, plating, heat-treating are other illustrations. In its simplest terms, the division between direct and indirect is based on how easily the cost can be figured. I have seen this distorted notion carried so far as to produce the strictest kind of accounting for all incentive time with absolutely no records, no production counts, and no actual times kept on indirect and "daywork" direct operations.

All this is so silly. What the management should be after is the correct cost. In the case of casting cleaning, for example, it often costs more than the molding and coremaking. Such operations should be measured and classified as direct labor. Any others that occur regularly to each piece should also be classified as direct labor. Of course, the distinction between direct and indirect has no bearing whatever on measurement. This becomes evident when we look at the job of measurement from the standpoint of getting everyone on incentive.

GOOD TIMESTUDY MEN

Obviously, we cannot solve the problems of coverage unless the timestudy men know how to measure the unusual types of work. We must have skilled timestudy men to measure non-repetitive operations. They must know how to make the maximum use of timestudies by the standard data method. This is where the difference lies. Of course, "it can't be done" by the ordinary methods of direct timestudy. Not only do they cost too much, but direct timestudies cannot provide incentive until after the non-repetitive jobs are completed.

Much that is called timestudy is as far from being timestudy as second-grade arithmetic is from being accounting. It creates a distorted opinion for the honest work that is being done in many plants. Unfortunately, some people think that a timestudy man takes a few observations and sets a "rate" on each job. By using such expensive methods, we have not made the progress we should have.

Managements are at fault also, in many instances. They have hastily concluded that incentives would solve their problems. Then, having picked on some likely looking young man, they have supplied him with a textbook and stop watch and instructed him to start incentives the following Monday morning. Maybe that is one of the faults of our mechanical age. More likely, it is due to ignorance of the fundamentals of sound measurement. It seems to me that a little concentrated analysis is what we need. Mature consideration of the factors involved would force us to conclude that there is a great deal more to good wage incentive installation than mere stop-watch mechanisms. A much bigger factor is the proper type of personnel. Even capable men cannot succeed, however, unless their methods are correct. In addition, the principles must be sound and the administration must be fair.

Bigger men will help in other ways. For example, the right type will not go along with some of the crimes perpetrated in the name of incentive. They will prefer to work elsewhere. They will have a more professional attitude toward their work and will refuse to do things that may be expedient but not correct. Men who can do a good job and stick by their guns not only will solve many of the so-called problems of incentive but will be acceptable for promotion into executive positions. They will be broad enough to understand that sound timestudy work is largely human relations, not stop-watch engineering.

CHAPTER 5

THE STANDARD DATA METHOD

Full coverage means that 100 per cent of all time-clock minutes are measured by standards. Such perfection is unattainable, especially in jobbing manufacture. But it is not impractical to expect a coverage of 85 to 95 per cent. To compare notes, I wish you would check your own per cent on standard. To make this computation, divide the total of all minutes on standard by the total of all time-clock minutes. What do you get for an answer? If it is anywhere near what you think it should be, buy yourself a good cigar.

One form of the ideal condition can be attained by using a "coverage plan" such as many firms introduced during the Second World War. Such a plan accomplishes this objective but provides only a group type of incentive payment. It has two distinct disadvantages:

1. Measurement and reward for individual performance are completely lacking.
2. Operation and part costs are not obtainable, and product profits cannot be determined.

WAGE COST CONTROL

The "coverage plan" did put everybody in the plant on incentive. But we should not overlook the two reasons for using such a plan. These were (1) to get going in a hurry, and (2) to provide a way to pay more money. Nevertheless, providing incentive opportunities for everybody is still an ideal well worth striving for. Unfortunately, however, we do not yet know how to completely gain that objective and at the same time keep track of costs by individual products. The latter is very necessary in order to stay competitive. Increases in earnings and productivity may be only temporary advantages if product costs remain unknown. Making and selling too much product at a concealed loss has put out of business more than one firm. As one Vice-president said, "If we lose a nickel on every one we sell and we sell enough of them, we are certain to go broke." There is little or no cost control without incentives, but the converse is not necessarily true. To gain cost control, you must have the means for segregating cost facts. When facts are available, the business management has at least three courses to follow in the effort to stay alive. It can continue the struggle to make profit by raising prices, reducing costs, and selecting customers. But the long-pull, progressive course is that of lowering costs—those of labor, indirect as well as direct, those of selling and distributing as well as manufacturing, and those of material and overhead.

To gain both objectives, cost control and incentive, we must sacrifice something. In this, it is the something less than 100 per cent coverage by direct incentive. Maybe, someday, this objective will be attained. The means may be through a distribution of reductions in costs created by "intelligent selfishness," as James F. Lincoln terms the cooperative efforts directed toward continuing the success of the business.

DIFFICULT MEASUREMENT

The drop from 100 per cent in direct measurement comes about because of difficulty in setting proper standards. The obstacles arise from several conditions:

1. Measurement cannot always keep pace with changes in manufacturing.
2. Timestudies cannot be taken economically because there are too many types of work done per employee.
3. Standard data, although available, cannot be applied because working conditions are changed without notice or methods to be used are not predictable.
4. Delays and interruptions prevent the doing of productive work, and these are rarely zero in amounts.

The four conditions limiting the attainment of 100 per cent coverage by incentive are always present. Nevertheless, in themselves they do not account for the low per cent coverage found in many plants. The chief reason for the low per cent of work measurement is that the timestudy methods used are not equal to the task. The direct, individual "rate-setting" procedure is too slow and too costly. These individual studies should be consolidated to build standard data.

WHAT IS STANDARD DATA?

Standard data is the recorded summary of many timestudies. It includes all the element standards required to perform a specific type of work. It may take the forms of tables and charts for convenience in application.

The standard data method is not something new. It was used by skilled timestudy men before the First World War. The essentials are shown on a form used in Midvale Steel in 1887.[1] Nor is it complicated. When everything is considered, it is simple in comparison with "rate setting" by individual timestudy. The simplicity might be emphasized by describing standard data as the result obtained from one great big timestudy that contains all the elements of a given type of work. On such an imaginary study, there would be many watch readings for each element. From the many readings, one "time" for each element would be converted by correct performance rating to that required by the normal, qualified person. A percentage for relaxation would be added to suit the type of work done.

But the element standards derived from one study, no matter how extensive, probably would contain only one set of points in the ranges of the job variables. This is where the illustration breaks down. Studies are required over the entire range of sizes in order to adequately measure all work of the type.

In reality, standard data is an extension of the same process that is used to arrive at one element standard from a number of watch readings recorded on a single timestudy. All the element standards on one timestudy are constant for the single operation observed. In extending observations to include many timestudies of a given type of work, certain of the elements continue to be constant. Others are variables. The standards for a variable are contained on a curve. The curve measures the relation between standard time and dimensional factor.

COMBINING TIMESTUDIES

But the point is that the same thing as one inclusive study is readily obtained by combining the results of numerous studies. The composite results would have many hundreds, perhaps thousands, of watch readings. These support each of the single value constants and the curves plotted for the variables. The standards are composites of many studies. These are taken by several timestudy men of a group of people performing numerous and similar jobs. Thus, element standards determined by applying correct performance ratings and relaxation factors, produce standard data that fairly measures the work included within its range.

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[1] Copley, F. B., "Frederick W. Taylor," Vol. 1, p. 230, Harper & Brothers, New York, 1923.

Next in importance is the inherent consistency of standard data. It provides consistency of time allowances because

1. Exactly the same time is allowed for a constant element each time it is part of the operation time standard.
2. Proportional time is allowed for each variable element as determined for a given dimensional factor from a basic curve for all sizes in the range studied.

From the foregoing, you can see that standard data is more easily explained to employees, supervisors, and union representatives. It provides obvious and ready means for adjusting standards to compensate for changes in methods, equipment, quality, and product. Most important of all, it affords an economical method for measuring output and rewarding effort on many occupations that do not now have incentives.

REPEATING ELEMENTS

Work measurement by the standard data method utilizes the repetition of work elements. The elements are carefully set apart in the preparatory timestudies. Then they are analyzed and compiled for easy reference. The basic advantage of the repetition of work elements is fundamental to economical standard setting measurement. It makes practical the measurement of some types of work that many now say cannot be put on incentive. This is our concern here. It means that proper incentives can be greatly extended to include many who "wait for dead men's shoes" to get the promotion that carries with it the "more money" required by the growing family. It means that the individual himself can do something about his own "take-home." It means that plus skill and plus effort can be rewarded immediately.

Incentives to pay more money for above-normal output can be set up for almost every type of work. The question is chiefly one of practicability. The answer to that hinges upon the method, as with most other similar questions. It remains then to show

how much more economically work can be measured by means of standard data than many people realize.

High coverage can be obtained when standard data methods are used. How the data method differs from "rate setting" can be emphasized by Fig. 3. The last column of figures shows percentages. These indicate the coverage that would have resulted if the timestudies taken had been used solely for "rate-setting" purposes. Instead, they were analyzed and combined. Arranged in standard data forms, they provided many times more widespread incentive opportunities. These figures are strong arguments for the standard data method. Its efficiency as well as its vastly greater consistency leave practically no valid arguments for continuing to try to get complete coverage by the direct

Operation	Number of Timestudies Taken for Data	Standards Set in One Year	Per Cent Coverage if Used for Rate Setting
Core making	60	7,500	.8
Bench molding	40	3,250	1.2
Snag grind	40	656	6.1
Hand grinder	20	300	6.7
Turret-lathe setup	25	1,000	2.5
Turret-lathe production	100	600	17.0
Auto-screw setup	30	600	5.0
Auto-screw production	50	600	8.4
Surface grinder	14	500	2.8
Shaper	17	150	11.3
Multiple drill	15	5,000	.3
Bender	17	2,000	.9
Planer	23	4,000	.6
Punch press	10	5,000	.2
Milling	35	244	14.3
Grooving	42	748	5.6
Turning	32	704	4.6
Planting	45	600	7.5
Hardening	30	300	10.0
Swaging	40	750	5.3
Wire drawing	21	2,500	.8
Visual inspection	53	422	12.6
End clearance	52	586	8.8
Special order	75	706	10.6

FIG. 3. List showing coverage that would have been obtained had studies been used only to "set rates."

timestudy method. From this standpoint, the discussions of continuous versus snapback, modal versus average, and similar timestudy details, are amusing. They remind us of the statement that backward peoples build their oxcarts stronger instead of making the roads smoother.

DATA FROM TIMESTUDY

Our thinking bogs down because we suppose that wage incentives necessitate timestudy. That is a correct supposition in many instances. Timestudy is the best way we know for determining the "fair day's work." But the mistake is in supposing that timestudies must be made of all jobs. That is not so. Much of any class of work is a repetition of detailed parts common to the type.

Incentive Terms	Letters of the Alphabet										
	a	c	d	e	i	k	n	p	r	s	t
Standard	x x		x x				x		x	x	x
Task	x					x				x	x
Price		x		x	x			x	x		
Piece Rate	x	x		x x x	x			x	x		x
Occurrence	4	2	2	4	2	1	1	2	3	2	3

FIG. 4. In the chart, a, r, and t appear in three of the four words commonly used to denote an incentive allowance. Three letters—d, k, and n— occur only once.

The simplest analogy is our alphabet. Think of the 26 letters of the alphabet as being element details in a given type of work. Just as a word is an arrangement of certain letters, any specific job is only a combination of some of the elements. An example of repetition is shown in the chart made up with 4 of the words commonly used to designate the incentive allowance for an operation (Fig. 4).

The illustration reveals that certain letters are used in 3 of the 4 words. Others are found in 2 of the 4 words. Only 3 of the 11 letters occur in but 1 of the words. However, the 11 letters include all the distinctly different ones there are in the 4 words. But, there are many more words that can be arranged from the 11 letters. Here are a few:

part
crank
insert
spacer
stripe
sand
pack
paint
dress
stack
kick press
crane
draper
carpenter
trainer
starter

This same general pattern is found in all work. Some elements occur in nearly all jobs of a type. At the other extreme, some elements are done to complete only certain jobs. This analogy based on letters of the alphabet typifies the usual trade or profession. It represents the "know-how" observed as actions when a work operation is performed. The 11 letters can be thought of as the total of a job requirement and any one of the words as an operation. Again, the 11 letters may be likened to the elements of a trade such as pipe fitter, typist, or molder, and some of the words to all the operations of the type performed in the plant.

TIMESTUDY REWORK

Maybe this is getting a little farfetched, but let's go ahead a bit further. You don't have to look up every word in the dictionary. You know the arrangement of letters that make up many words. Some you have to check. So do I, because my spelling is not what it ought to be. The same thing applies to operations within your ken. You know what elements should be performed without looking. Why then is it that we timestudy every job? Some men timestudy the same group of elements every day.

Sooner or later, they get to be like a gray-haired man I knew "once upon a time." He had taken timestudies on grinding for so many years that he knew what the element standards should be. He had mental standard data. It was supported by long experience. He knew most of the answers but continued day after day to retime elements he had recorded thousands of times before. To me, that was such a waste of time and effort. Just think how much better off he and his company would have been if his studies and experience had been properly summarized in recorded data.

MIXING COMPENSATION WITH MEASUREMENT

Thus far, we have talked about standard data in principle without regard for wages or task level. Now I feel that we must detour. We should get together on these two factors. My reason is that standard data should be standard. We should strive to gain uniformity. This cannot be done if we have several yardsticks. But this variety is due in part to the wage factor. Whether the chicken or the egg came first is not the question. Before we go further, we should understand the difference between work measurement and base wage. These two have been mixed until many people cannot see a distinction. In part, this confusion results from long use of piecework with monetary rates. Also, it comes from the extensive use of the low-base-rate, loose-standard incentive plans. Both types have considered compensation primarily without regard for work measurement.

Much of the mixed thinking has been carried over from the many types of contrivances that were "figured out" from past performances. These abortions were at the root of most of the negative reactions to wage incentives. They were the chief reasons why we had "rate cutting." There were other reasons, of course. Many resulted from poor timestudy. These have been discussed in part in earlier chapters.

In the past we used piece rates, Halsey 50-50, and many other mixtures of compensation and measurement. In most instances, there were no timestudy observations made to establish time or money allowances. In other situations, the timestudies were of little or no value, having been taken by untrained people. Perhaps, as I saw recently, the timestudies were actually disregarded and the incentive basis was figured from the machine capacity.

LOOSE STANDARDS

Many such plans were worked backward in trying to adjust for a difference in a wage level. For example, in a number of plans, the man was paid $.40 an hour and was expected to make $.40 more, to attain an $.80 take-home comparable with that of similar jobs in the area. If now he is paid $1.00 for the same job because they pay $1.00 across the street, then the level for the incentive must be made consistent with it.

Unless the standards have been revised accordingly, the cost includes two payments for the same thing. It includes the cost of the extra time allowed in the standard to offset the low base rate. It includes the pay raise. The extra time allowed is equivalent to an increase in base rate and applies as a percentage multiplier to every increase added to the hourly rate. So it happens that those plants with standards set loose to make up for low base rates will have excessive costs. The wage scale is moving up independently of the time allowances. The higher the wage rates go, the greater will be the distortion.

Loose standards can be consistent and can operate successfully with an incentive plan. The point is, however, that hourly rates are becoming more and more uniform for each class of skill. Notice the increasing tendency toward the payment of the same base rates for like occupations in a community and even in an industry. Increasingly, the base rates are being determined from the same basic job-evaluation plans. The National Metal Trades Association plan is the one often referred to. Industry-wide bargaining could bring on the same hourly rate everywhere for a class A lathe hand. This trend makes it necessary to take out of standards whatever looseness was put in to make up for low hourly rates. This is the same problem being struggled with by those folks who were foolish enough to loosen incentive standards during the war when wage stabilization held down the hourly rates.

MEASUREMENT AND COMPENSATION

But the point is that there is no uniform measure of work done when the incentive base varies between plants. There is no standard definition of a fair day's work. The yardstick has different lengths. The differences in length greatly exceed the variations between the several pattern-shop shrink rules. Looked at from one side and assuming comparable base rates, the differences are reflected in unlike earnings and, hence, costs. From the other side, the earned rates may be comparable, and the differences in work standards will then be shown as differences in base rates.

Looking backward, it is evident that all these practices violate the fundamental principle of work measurement. In the future, we must clearly understand and correctly apply that principle. The measure of work must be distinctly separated from the rate of compensation. This is a necessity because rates of pay are subject to change perhaps once a year, or oftener, if there is a "reopening clause" in the contract.

The distinction between compensation and measurement must be clear. The compensation will be determined by economic conditions and the results of negotiations. On the other hand, measurement is something distinctly different. A fair standard time should bear no relationship to the rate of pay. This statement presupposes only one job class per operation. Said another way, there should be but one fair standard time for performing a given operation in a specified manner. This standard should be built from valid timestudy observations. It cannot be a fair measure of work done if it is juggled in any way to offset inequities in base wages or existing incentive allowances.

BASE RATES

To move on toward our objective, we will deal with the base rate first. In money, it may be negotiated or worked out through wage survey. But what the wage rate pays for is our concern here. The "what" has an important bearing on work measurement. We must define what is expected in return for the base rate. It should be worked out by job evaluation. The definitions of job contents should be specified in the job descriptions. In theory, the job description spells out the requirements for skill and knowledge. We think of these as representing the definition of the normal qualified employee.

Some job descriptions are well written. Many are poor. Some are hastily done and, often, are written by people who are not acquainted with either trade knowledge or terms. At best, however, descriptions are set down in words. Many of the words are general. They must be interpreted. But job specifications are definite steps in the right direction. However, we must improve our understanding of the importance of good job descriptions. Then we must learn to set them down in specific wordings. Better definitions are necessary to more exactly separate compensation from measurement.

With perfection in this field, we have only the definition of what we mean by the normal qualified employee. Such a person is a mental image. He does not exist actually. As a matter of fact, the experts tell us that every one of us is different. Further, they emphasize the desirability of treating each person as an individual.

THE AVERAGE MAN

We do have unlike skills and abilities. We have inconsistencies in training and learning. Presumably, however, the base rate pays for some defined amount of skill. We say that the person who meets these specifications is a "normal qualified employee." It is for this specified individual that standards should be set. They should not be established for John or Mike.

That principle is a necessary foundation. It is wrong to think or talk of the "average man." The average man exists, of course. He is a statistic. But, as a statistical thing, he changes. When Uncle Sam took a great many men and women into the Armed Forces, the average of the remainder shifted. When they came back to the plants, we acquired different averages. Thus, an average is always changing. Some evidence of this shows in statistics from Army issues (Fig. 5). Notice how the clothing sizes have changed in just 25 years. But a job description should not change because a different man is assigned to the work. If it does, it is not a specification of work or skill. The job description should be constant for a specified type of work. It should be revised when there is a change in the work content. The same applies to a work standard. It varies with the work content. It measures the amount of work that should be done for the base rate. At the same time, a standard should be based on the skills specified and implied in the job description of the normal qualified employee.

DIFFERENCES IN SKILL

If the standards expect a higher skill than the job description calls for, they are unfair to the man. If, as is often the case, the standards allow extra elements because of lower than normal skill, they are unfair to the consuming public and to the company. Fair standards must be based on the normal skill of the job class that includes the work being measured. More specifically, the elements allowed in the standards must correspond with those required of the normal qualified operator. This is an important fundamental sometimes overlooked.

For emphasis, we can restate this fundamental in a different way. Remember that all the men doing a type of work have different skills and different degrees of the same skills. But under standardized rates as set up in some job evaluation plans and many union contracts, all employees in the same job class would get the same hourly rate. Yet, each individual in a given class has a different combination of actual skills. Hence, only by means of sound incentive plans, in my opinion, can we fairly compensate for these

EXTRACTS FROM ARMY SIZE TARIFFS FOR CLOTHING
(Tariffs derived from issue records and show issues per 1,000 men)

Caps

Size	Year 1923	Year 1935	Year 1948
6⅜	5	2	9
6½	14	5	40
6⅝	33	11	24
6¾	120	35	95
6⅞	212	114	195
7	298	253	296
7⅛	173	242	155
7¼	87	175	116
7⅜	26	95	30
7½	28	46	27
7⅝	4	13	4
7¾	...	6	7
7⅞	...	3	2

Shirts, Cotton (Neck Size)

Size	Year 1923	Year 1935	Year 1948
13	...	...	2
13½	1	1	41
14	7	7	180
14½	17	17	352
15	237	237	224
15½	391	391	138
16	217	217	44
16½	...	...	10
17	104	104	8
17½	...	...	1
18	22	22	
19	4	4	

Boots, Rubber

Size	Year 1923	Year 1935	Year 1948
6	62	62	33
7	255	255	104
8	321	321	164
9	220	220	275
10	108	108	241
11	28	28	120
12	6	6	63

Leather Belts

Size	Year 1923	Year 1935	Year 1948
28″	...	...	7
30″	...	194	140
32″	...	...	170
34″	232	652	324
36″	...	...	115
38″	646	136	90
40″	...	...	70
42″	104	12	40
44″	...	...	30
46″	17	5	10
48″	...	...	3
50″	1	1	1

Drawers

Size	Year 1923	Year 1935	Year 1948
28	2	2	
30	20	20	578
32	352	352	
34	322	322	305
36	169	169	
38	77	77	104
40	39	39	
42	12	12	12
44	7	7	
46	...	2	2

Socks, Light Wool

Size	Year 1923	Year 1935	Year 1948
9	...	12	7
9½	...	19	8
10	...	287	29
10½	...	267	303
11	...	311	408
11½	...	81	170
12	...	23	63
13	...	...	10
14	...	...	2

FIG. 5. Notice how the clothing sizes have changed in 25 years. These figures show marked changes in the "average" man.

differences in skills applied. The man who can and does turn out more, is paid more under sound incentives. Keep in mind that here we are talking about skill—not effort.

SKILL AND EFFORT

Effort is another phase. It is essentially *degree of application of a given skill.* So that while we usually think of incentive as rewarding for more effort, the net result paid for is a combination of both effort and skill. Let's explain in arithmetic. When a man having just normal skill applies 25 per cent extra effort, his premium will be 25 per cent for the time worked on a one-for-one incentive plan. Assume, on the other hand, that he had 25 per cent more skill than the normal qualified employee. When he applies his extra skills working only at the normal pace, then too he will earn 25 per cent extra under the same plan. Now we come to the actual condition that many of us do not understand. We fail to recognize that the everyday result of incentive is the combined result of skill and effort. For example, the combined effects of plus 25 per cent effort and plus 25 per cent skill are not the sum but the product. The extra earnings are 1.25 × 1.25, or 1.56¼. The effects of the combination of skill and effort are shown in Fig. 6.

	PLUS EFFORT										
PLUS SKILL	0	5	10	15	20	25	30	35	40	45	50
0	0	5	10	15	20	25	30	35	40	45	50
5	5	10	16	21	26	31	37	42	47	52	58
10	10	16	21	27	32	38	43	49	54	60	65
15	15	21	27	32	38	44	50	55	61	67	72
20	20	26	32	38	44	50	56	62	68	74	80
25	25	31	38	44	50	56	63	69	75	81	88

FIG. 6. Table shows the increases in rounded per cent earnings possible with combinations of plus skill and plus effort.

EXTRA SKILL

Skill has many definitions. Here we will set down a homemade one. Along with it is a definition for effort that we may need later on.

1. Skill is the "quality," including knowledge, experience, dexterity, and the like, that goes with ability.

2. Effort is the "quantity," including diligence, speed, and productivity, that goes with application.

Skill shows up in differences in method or elements in a job. It is the addition or the elimination of movements or elements of work—assuming, of course, that the production is up to standards of quality. One of my more obvious examples is of the man who can "get a size" in a setup with fewer tries and less adjustment than the normal allowed.

An amusing story that exaggerates the effect of skill may emphasize the point. The operation involved the cementing of soles to the uppers of tennis shoes. The completed shoes were hung on pegs on trucks in order that they might dry properly. The trucks were placed behind the operator. After the standards were set, one operator began to earn double wages. Eventually, it was discovered that this highly skilled operator did not have to turn around to place his work on the truck pegs. He was able to toss the finished shoes over his shoulder without looking. He had formerly been a juggler.

This illustrates why the timestudy man would have to recognize that the act of juggling was abnormal in the operation. He would have to allow for "turning and placing" the shoes on the pegs even though the juggler did not need to do so. The other recourse would have been to raise the base rate so as to hire enough jugglers to perform this particular operation and omit those elements of work from the standards. Certainly the illustration is every extreme. It does serve to point out, however, the important service that well-prepared standard data can render in measuring the amount of work to be required of the normal operator.

FAIR DAY'S WORK

Standard data is basically sound at any time. It is inherently consistent because it is a composite of many studies. The true constants and variables are analyzed and recognized in its preparation. Variations in rating and methods are eliminated in its coordination. In completed form, standard data allows exactly the same times for identical elements of work. This procedure not only has all the advantages of economy and consistency, but also it makes for uniformity in task levels throughout.

Standard data is a composite of many studies taken by several timestudy men of a group of operators performing numerous jobs.

Therefore, it is a representative measure of the normal skill requirements for that type of work. This normal skill is something that cannot be defined by our job evaluation and analysis methods as we have them today. And yet, our base rates represent payment for a normal skill despite the fact that no two operators are alike. Some have more and others less than normal skill. Obviously, the variations are taken up in differences in incentive earnings. This truth should be recognized. We are doubly confused when we argue (1) that premium earnings should be about the same for everybody, and (2) that people should not be allowed to earn more than so much premium.

In the measurement of plus skill, standard data can provide what is probably the fairest method of reward. Certainly a consolidation of many timestudies will come closer to establishing a representative normal work requirement than any other means now available. From that basis, then, skills in excess of the base rate compensation when applied will be rewarded through increased premium earnings.

NORMAL EFFORT

Having set apart the skill factor, we come to the measure of effort. Strangely enough, this is what many people think of only as the end result of incentive. It is one of the factors we include in the term "speed-up." It is expressed again in the words "work harder."

All of us who try to get ahead do work harder or more often. The greater pace is the rate that we refer to in the term "effort." This factor of effort or pace is exceedingly important in timestudy. It is expressed as a ratio of the pace observed to that specified as normal. It is called "performance rating." It is the means for translating the actuals observed to a standard.

To some managements and timestudy men, rating means nothing. They do not know that fair standards cannot be set unless the performances observed are rated in terms of a "normal." They still think in terms of average times. These are unfair and inconsistent. Averages of poor performances produce loose standards. Averages of best operator times result in tight standards. One cannot select a normal performance without being skilled in rating pace.

Rating is the appraisal of the actual pace at which the work is being done. Rating is vital to current timestudies because the actual pace may be anything from 50 per cent to 200 per cent of the normal sought. It goes without saying that herein lies an important variable in timestudy procedure.

TRUE MEASUREMENT

But to gain consistency in ratings, it is necessary to have a constant yardstick. We need a measure that does not change from one department or plant to the next. The yardstick should be the same in good times and poor. The reason is that there is but one fair time to perform an operation under a specific set of working conditions.

This can be attained only by having a bench mark or common base of reference. Such is the objective sought in the work of the National Rating Committee of the Society for the Advancement of Management. It is planned to obtain motion-picture films of typical operations and establish known rates of operator performances for them. These can be used as bench marks because they can be shown at identical projector speeds anywhere in the country. Thus, a common basis for measuring work performance can be developed.

There are two benefits to be derived from film standards of known performances. Most important, they can provide the basis for establishing a uniformity in task level. Then, with like base rates and like performances, the "take-home" will be practically the same. Timestudy men can use such films as gauges to measure their ratings. Standardized films can be made to provide training for timestudy men and others in correctly judging the actual performances being studied. Thus work measurement and incentives could be brought to the same standard of expectancy.

NORMAL OUTPUT

It appears increasingly important to get uniformity in the task level or work measurement standard. The standard day's work should be made more uniform. One way is that described by Professor Ralph Barnes,[1] who urges community surveys. The procedure is logical. It is the one followed by both managements and unions in comparing wage rates. And with surveys, the normal standards would eventually approach a common level. Without uniformity in the measure of a day's work, the correction of inequalities in wage rates will magnify those inequalities and throw them over into greater differences in "take-home."

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[1] "Is the Rate of Output Right?" Production Series 16, American Management Association, 1945.

The solution to the problem lies in a common understanding of a normal operator performance. Normal is not average. Average is highly variable and changing. "Average" is a term that should be crossed out of the timestudy language. Especially should it be omitted from contract clauses purporting to define the basis for wage incentives.

THE YARDSTICK

To get away from the variable average, we must adopt a standard. That standard will be like the yard, pound, and quart that our ancestry adopted. In the case of a standard pace for a day's work, four other influencing conditions should be specified. Preferably, these should be standardized also, to avoid much that confuses employees and managements.

1. *The basic wage.* I refer here to the proportion that base wage is of expected earnings. The incentive plan design may anticipate anything in our experiences from 0 to 100 per cent premium over the base.
2. *The incentive formula.* This may be influenced by a calculation of the premium that results in less or more than 100 per cent or one-for-one.
3. *The rating base.* Plans call for rating in terms of both standard or expectancy pace. Another form of description is "low task" or "high task." Is the base the "fair day's work" or the expected rate of incentive performance?
4. *The relaxation factors.* These may include all kinds of things. Personal and allowances for fatigue are the usual ones. But wash-up, lunch time, delays, material fluctuations, and even setups are variously included.

We must keep all these influencing factors in mind when comparing normals. Many people are beginning to see that earnings per hour, wrong as they may be, come closest to resembling a common measure. The basic error in such comparisons is that it contradicts incentive as a premise. Disregarding the incentive plan design, people may be making higher earnings in one plant than another because production is not restricted.

But if we are ever to have a standard of pace, we must define it in terms of the four factors mentioned. With this analysis, I can mention the measure of pace I have used for about 30 years. It presupposes

1. A base wage equal to the community level or slightly above with premium earnings expectancy of 25 per cent above the base for good work produced on incentive.
2. An incentive formula that pays 100 per cent premium for performance over standard at the base rate of the work done.
3. A rating base in terms of 60 *units* per *hour* equivalent to the job evaluated base rate.
4. A set of relaxation factors that vary from 15 per cent upward according to the strenuousness of the work. Some are over 100 per cent. The usual range is from 15 up to 35 per cent. As a rule, all delays, work variations, setups, and like indirect times are strictly excluded, to be paid for separately with standard time allowances or at base rate.

Remember these qualifying conditions when you consider the standard for pace that I recommend. This standard for *normal* performance is something that defies word description. So it is expressed in terms of an example. The one I prefer is

> *Normal pace is equivalent to dealing 52 cards in four piles in .45 minute.*

The four piles are spread about as we toss cards in dealing four hands of bridge on the common card table. They are not placed in neat piles. The time of .45 minute is an over-all, beginning with the start to deal of the first card and ending with the drop of the last card. Its equivalent in walking pace, as nearly as I can relate it, approximates 3.2 miles per hour.

All this discussion on rating is not properly a part of this text. But I have included it because it seems necessary. I want to avoid your making the comment George Wilkinson made of "Timestudy for Cost Control." He said, "You lead us up to the trough, but there is nothing in it to drink." He meant that the book should have had more "cost control." Mentioning a standard for pace seemed necessary here. If it were not stated, you would ask yourself the question every time we refer to standard or normal element value. Having made this detour, we can go on now with our main channel of explanation.

CREATING INCONSISTENCY

A negative reason for using standard data is brought on by certain clauses inserted in union contracts. These clauses have to do with the revision of incentive standards made necessary by method and product changes. Some clauses contain wordings that read, "Standards will be changed only in the elements affected by the method changes," or "Only the changed elements of the operation will be retimed."

Some union clauses provide for the revision of standards when there is a "substantial" or "major" change in method. Others substitute a definite percentage like 25 per cent. Such provisions for "sharing the wealth" cannot do other than lead to the ultimate destruction of the incentive reward. Moreover, the marked inconsistencies created in earning possibilities will lead to grave industrial relations problems on the one hand or restricted productivity on the other.

Such negative clauses may be forced into labor contracts for purely selfish reasons. The selfishness is the same as yours and mine. All of us would like to get something for nothing. If you disagree, then try to explain why slot machines, sweepstake races, and speculative stocks have so many interested donators. Undoubtedly, there is behind some of these clauses the intent to maintain past earnings that include some amount of looseness. The looseness has resulted from accumulations of errors, concealed method changes, and compromises. It is unfortunate but true that some managements go along with the faulty practice of neglecting to maintain standards consistent with work done.

The clauses are designed to protect the employee against "rate-cutting" practices that have prevailed in some plants in times past. Furthermore, they are designed to protect the earnings of incentive people against errors made by the timestudy man who set "rates" from individual timestudies. Lastly, and mistakenly, such clauses may be intended to preserve whatever looseness has existed in the standards prior to the method change. Such negative clauses are insults to timestudy men, managements, and unions who try to set up and maintain fair measurement.

CORRECTING ERRORS

The protective clauses have as their broad purpose the establishment of procedure to be followed when standards are or will become loose. That is important to remember because management and timestudy men expect to correct the errors that are on the tight side. And everybody in the shop moves heaven and earth to get the low ones moved up to the more generous standards.

However, one union official has argued that errors in either direction should be corrected so as to have all the standards consistent. Perhaps someday union officials will agree that consistency is better, fairer, and less troublesome. They may insist upon correcting errors in both directions.

At the present time, it seems important to maintain guarantees that standards will not be revised except for changes in methods, equipment, quality, and other factors that alter the conditions of work. At the same time, it seems only reasonable to avoid the perpetuation of mistakes. We should start with a sound foundation in the establishment of any new standards for new designs and new operations. We should definitely avoid the practice of "applying" an old standard to a new job.

In revising standards, basic data offers a tremendous advantage over the individual timestudy. With data standards, it is a simple job to add or subtract the elements of work that are affected by a method change. The majority of such changes can be made within the limits of the data available. Timestudies are necessary only when the change introduces elements of work outside the limits of the recorded data. However, this convenience should not be twisted around to permit any form of restriction on the taking of actual timestudies under any conditions where the Standards Department feels they are needed.

EMPLOYEE INTERESTS

The interests of the man himself are served by standard data in several ways. In the first place, the data method can be used to measure correctly and economically almost all types of work. Second, data affords a ready way to explain the relative equitableness of any standards that are questioned. It permits of the same types of explanations of differences that analytical job evaluation does for the underlying base rates. Third, standard data establishes consistent earning opportunities. This eliminates many grievances. Fourth, standard data furnishes a sound, explainable, and obvious means for adjusting standard time allowances when work is added to or subtracted from an operation. This obviates the tinge of the so-called "speed-up." Primarily, however, sound data provides the fairest method we have developed for measuring the normal work requirement. As we tried to explain in the earlier pages of this chapter, data sets a measure of normal skill and effort. This, shall we say, automatically compensates those who apply plus skill and plus effort. And with the one-for-one plan, the compensation is in direct proportion to the amount put forth. When this advantage is coupled with individual incentive, the employee gets both fair reward and fair measurement for his own skill and ability.

SUGGESTION PLAN NECESSARY

Enlarging upon the changing of standards brought on by methods improvement, it seems important to introduce here some comments on rewards for suggestions. There are many suggestions in any progressive firm. Evidence of this is seen in the extensive publicity given to the subject in trade magazines. The employees themselves can and do contribute many ideas for improving processes. Such individual ingenuity should be rewarded adequately, according to my way of thinking. The amount of the award should be stressed because many plants do not have successful suggestion systems. Part of the difficulty lies in the smallness of award. The usual percentage paid is much less than the premiums that would accrue to the employee if he could continue to take advantage of the improvements while retaining the old standard on the job. The first reaction might be that the problem should be solved in this way. And, it should be emphasized that under a plant-wide or Halsey 50-50 type of incentive plan, the result would probably be just that. On individual incentive, however, the effect of improvement is to make some jobs much easier to perform than others. Thus, premium earnings get all out of line. But remember, the cost to the company, and hence the consumer, remains the same. The inventor is working for himself only, without regard to the future of the company.

CREEPING CHANGES

Until suggestions are turned in, standard operation times become looser and looser with or without restrictions in production. During that time, prices continue higher than need be. Eventually, the plant is faced with abandonment of the incentive plan or the scourge of "rate cutting." Neither outlook is constructive, especially in view of competition.

Undoubtedly, much more educational work is required to point out that ideas for improving methods should be turned in as suggestions. This is for the benefit of all and for the future success of the company. This will entail considerable emphasis on the fact that a correctly revised time standard permits the same opportunity to earn a fair incentive premium as the job standard did before the suggestion was made. Also, it will require considerable explanation of the facts of job security. Of course, a man's job may be secure if he has top seniority—that is, until the plant folds up. Seniority is not the answer. We need more explanations of how jobs are created, how costs affect sales and consumption, and how prices determine who gets the order.

GIVING CREDIT

Beyond these, we have to do more than pay well for cost-reducing ideas. We have to give credit and publicity to those who make worthwhile suggestions. And in addition, we have to put the ideas into operation. All three parts are necessary to a plan that is successful in getting a flow of practical cost-cutting ideas.

But there is an important part that standard data can play in this success. It can serve as the basis for assembling the predicted cost reductions. Such figures from standard data are impersonal. They avoid some criticisms of partiality. Also, standard data is very useful in providing rapid means for adjusting standards to the new conditions.

DATA ADVANTAGES

Recorded standards have many advantages over those obtained by direct timestudy. They are impersonal, more correct, and ageless. In addition, they afford a sound and broad foundation for recognizing individual accomplishments, increasing profits, and meeting competition. These objectives are aided by standard data when used with wage incentives in at least five ways.

First, the standard data method is considerably less expensive than direct timestudy. It affords an economical method for measuring individual output. By individual measurement, we can recognize each person's skill and ability. The increased earnings can be in direct relation to the output of each individual.

Second, work standards set from recorded data are consistent because they allow the same element times for the same operations. This consistency reduces to a minimum the industrial relations problems that go along with wage incentives. It aids in the settling of such complaints as do arise. The revisions necessary to keep pace with improvements can be made with this same consistency. All standards and their revisions are easier to explain from recorded data.

Third, recorded time standards are impersonal. They eliminate many of the arguments that exist in the individual "rate-setting" process. And don't jump to conclusions. Much of this same advantage applies with the actual timestudies taken for data purposes. Here again, the standard for the employee observed will not be set from *that* study taken by *that* timestudy man That study is included with the many taken before any operation standards are set.

Fourth, standards set from data are fair. The data is built up from many studies. Therefore, it represents a fair measure of normal skill and effort. And because the same element standards are allowed whenever those elements of work are required, this measure of normal is continuing. Thus, differences between individual outputs are fairly measured and rewarded.

Fifth, recorded standard times permit the predetermination of labor costs for new and changed products. This feature alone is exceedingly important to progressive managements. It takes out many of the hazards of new ventures. Also, standard data makes for lower costs, better deliveries, and more correct pricing, because it permits more complete application of wage incentive to both direct and indirect labor operations. These advantages produce a higher average rate of productivity. As a consequence, overhead as well as direct and indirect labor costs are lower. Obviously, too, the more widespread the measurement of work, the more correct will be the individual costs of operations.

These five advantages are too important to be overlooked. They are many times more constructively useful than all that could be cited for the individual timestudy method. Therefore, my belief is that we should convert to the data method. We should cease the creating of inconsistencies. We should get away from the feuds arising out of personality clashes. Only by the standard data method, as I see it, can we fairly reward all those able and willing to work.

CHAPTER 6

IMPROVING TIMESTUDY METHODS

"*Why?*" is the question you ask when you see something off color in the shop. You want the wasted effort to be eliminated at once. Now, confidentially, shouldn't we look at our own work with the same critical eye? Shouldn't we ask "why" about a number of things we do regularly?

Are you one who insists upon perfecting the method before setting the standard? Is it because you fear that the operator will eliminate some elements and get paid for work he is not doing? What would happen to some of our procedures if incentives were applied to timestudy work? How about taking a look with the same attitude of constructive criticism?

If we look carefully, we will find a number of details to be worked on. Some were discussed in Chap. 4. Then, in Chap. 5, the attempt was made to show how to make more use of our timestudy results. In between, there are some points that I believe we can discuss with profit.

LET'S GET GOING

If you see this problem as I do, then the first step is to go to work. Also, enough man power must be trained to get the coverage we seek. However, even an army of timestudy men cannot adequately measure miscellaneous operations if they use the common "rate-setting" methods. The approach has to be through the use of standard data, as we tried to show earlier. There are several reasons.

Most important is the necessity for establishing standards before the work starts. To set standards in advance, you must have standard data. You have to set standards ahead of time to avoid creating the impression that payment for work done is figured backward from what management wants the employees to make.

Second, the cost of standards is a big factor to be considered. So also is the cost of not setting them. But more constructive is the fundamental economy attained by the data method. It is basically the principle of repetition applied in the field of timestudy. It is utilizing the elements of timestudy over and over again. The elements of a trade or type of work do repeat multitudes of times even where no two jobs are alike.

Now, obviously, it does require time and skill to group element standards into job standards. However, it is very much less expensive to group elements by charting and by the use of mental skills than by looking at the job through the actual timestudy approach. Some figures may serve to illustrate.

A test was made in a plant using the direct timestudy method. It showed that each timestudy man was setting an average of 5.7 standards during an 8-hour day. Another test made on similar operations in another plant utilizing standard data showed an average of 40 standards in 8 hours. This was equal to an average time per standard of 12 minutes each. The cost per standard by the direct method was $2.25 each and by the standard data method was $.32 each, at the going rate for timestudy men. The cost by the direct method was seven times as great as by the standard data method for similar operations. Of course, you realize that each of these costs is a variable. The cost is determined by whatever is required to establish a standard by the details involved in direct method, or by the procedure used with the standard data process. But here, we want to bring out some details that can be used to improve our methods.

RAISE THE SIGHTS

In the progress we seek, an important element is the right attitude. To overcome the difference between good measurement and ordinary "rate setting," the timestudy man must see his work the same as an engineer does, regardless of what he calls himself. He must measure all work and painstakingly *sift out the wastes.* He must remember that he sets the foundation. The whole planning and cost structures are built upon his standards. To illustrate, if he carries his standards out to five decimal places—some do, you know—then everybody in the whole organization will religiously continue with all five places. We can phrase this point about setting the foundation in even stronger language. My wording is, "The timestudy man signs a company check when he sets the standard."

SIFTING OUT WASTES

Changing to correct measurement should not affect the earnings of those on incentive except to increase the incentive opportunities by setting standards for all work. However, fairness requires that the employees be allowed time for all work required of them and for delays encountered by them. This is the kind of measurement that will permit attainment of the highest productivity. It separates and points out all the irregular conditions. Right in this particular lies the key to important increases in output that will be overlooked indefinitely as long as timestudy men continue to be just "rate setters."

We should learn how to make effective the important management tool we are responsible for. We can make it much more analytical and revealing. We must show up the weaknesses in operating conditions so that constructive efforts can be made to reduce or eliminate them. This is vital because it is a direct method for controlling management errors. The reduction of these weaknesses brings about an equivalent increase in production. But equally desirable in many respects, it improves the attitude of the productive force by reducing the number of aggravating interferences. The improvement in morale adds further to the higher productivity we seek. This doubly important phase of good timestudy was ably summarized by Carroll E. French, Director of Industrial Relations, NAM. He said, "Above all, I believe that only an efficient management, a successful and profitable company, can earn and hold the respect and cooperation of its employees."

INCOMPLETE TIMESTUDY

To begin the analysis of timestudy methods, let's start with a comment we often hear. What is your reaction when the timestudy man says, "I won't time the job. The method is not right"? Will you agree that this can be an attitude of mind that has held down the per cent on incentive to about 50 per cent? But that is not the only objection I have to it.

When you insist upon correcting the methods before taking the timestudy, you pass up the opportunity to get observations of work irregularities. Some unskilled timestudy men even go so far as to omit them from the timestudy. Their mistake is in assuming that these non-standard conditions will never occur again. Consequently, when the variations do creep in, two alternatives are open. One is to take a special timestudy. The other is to say, "Let the job go as daywork." Carrying their point of view to the next step, they can see no good reason for timing "small lots." At the extreme, they would throw up their hands at any attempt to measure maintenance work, toolmaking, or clerical operations.

This same attitude of mind may lead the timestudy man into another dangerous and blind alley. He may not keep pace with revisions in standards due to change of methods. You might call this laziness. Whatever it is, there is no escape from the ever-present problem of maintaining fair standards. Failures in and of themselves usually do not cause the trouble. The real difficulties arise from the patchwork remedies applied in other directions to offset the odious conditions created by the failures to correct for changed conditions. Two wrongs never have made one right. Incorrect and incomplete maintenance soon allows a soundly established incentive plan to become as inconsistent as one set up by poor timestudy. The earnings become irregular and inconsistent. Restriction of production usually sets in. Grievances pile up. Compromises establish precedents and the spiral is started. When management thinks this has gone too far, it usually tries to stem the tide by saying "No!" Then the cases go to arbitration.

TIMING MISCELLANEOUS ELEMENTS

All this discussion about one detail may bore you. I hope not. To my way of thinking, its application can make or break coverage. For that reason, my belief is that the most necessary change in attitude toward timestudy is with respect to what I call timing the miscellaneous elements. You may call them foreign elements. Whatever the name, they are irregular from the point of view of any good timestudy man seeking perfection in methods. All of us who know what we are doing seek perfection. That is a laudable goal. The application is something else and involves the use of common sense or commercial instinct.

Irregularities show up during the timestudy. At that point or even before, we can refuse to take the timestudy. Progress stops. At this fork in the road, we may part company. If you take the path of discarding them, you will wind up with low coverage. If you choose to go along the other path with me, you can get much greater coverage. And the first step is to understand that irregularities will occur in any shop, time and time again. Refusing to time them or throwing them out of the timestudy means that you will not have any measurement of these extras when they repeat again. And repeat they will. The next step toward greater coverage is to realize that it is more important to study the miscellaneous elements than the regular ones. The regular elements can be studied at any time. They occur in all jobs of a type. But the irregular ones happen only under certain conditions. Maybe an analogy would help to emphasize the point. You recognize that the extreme sizes of a range are the unusual ones to study because they rarely occur. You know that you must concentrate upon observing those extremes in order to complete your data within a time limit. Your reasoning is that you can study the average jobs at any time you go out on the floor.

We must realize that irregular or non-standard conditions will creep into shop operations because we are always striving for higher and higher perfection. "Mass production" is another term. The closer we come to perfection the relatively more often we will slip back from it, because of non-standard conditions. Therefore, it becomes very important that we measure the irregularities in order to gain total coverage. We have only three choices. We can (1) let the job go as daywork, (2) let the man take the bitter with the sweet by burying a vicious average in the time allowance, or, (3) measure extra work and properly compensate for it. The latter choice—that of measuring and compensating—is the only one you have, if you continue along the path toward total coverage and fairness, strict fairness, in incentive. Maybe I can summarize this by saying

> *We must be able to change standards faster than the shop can change its mind.*

MORE SKILLFUL TIMESTUDY

Our point of view must be that we give more attention to the difficult elements than we give to the regular ones. This is a necessary point of view. But you must follow it up with proper training. If you are not skillful enough to time the irregular elements you cannot tackle the more difficult jobs. One of the more difficult jobs to measure that you regularly see is the setup. In job-shop work where a man has four or five jobs per day, he would be on incentive only a small portion of the time if the setups were not covered. Obviously, to attain full coverage, standards must be set for the setups. To go on, the timestudy man who cannot record what takes place in an irregular or a setup operation will be completely lost when attempting to measure maintenance, tool-room, or similar operations.

Along with a change in attitude goes the necessity for acquiring skill in making finer breakdowns. Finer watch readings are necessary for two reasons. One need is to separate the small irregularities from the useful work. The other is to get basic standard data.

We have always looked down our noses at an "over-all time." We know that it is meaningless. It reveals nothing with respect to what was done. In between the over-all and the necessary type is the rough breakdown taken by the "clock pushers." Yes, there is more detail on the "rate setter's" timestudy. But not enough. Another study must be taken for any small revision. Let me use a story as an example. This happened in two plants during the Second World War. You may remember the shortage of timestudy men. Uncle Sam took about half of them. Promotion took most of the remainder. But production was vital. Incentives were urged. So in these two plants, we started full blast to get standard data. In both places, the boss men said, "We have file cabinets full of timestudies." "Fine," I replied, "let's get them out and begin." "What will we take first?" was was the question. The recommendation was, "Those studies of the work taking most of our timestudy effort."

In one plant, everybody said in chorus, "We should begin with Drill Press." To start the project, they got out all the studies and began to inspect them. My instructions were, "Look at each study and determine if it can be used for building standard data."

There were two piles of studies when I got back the following week. One contained the discards. The other included those that appeared to be useful. My recollection is that the pile of those passing inspection was about 15 per cent of the total. Then my suggestions were, "Now recap all these selected studies on Comparison Sheets. Plot the variables on curves. Summarize the constants." To make a long story short, they wasted the next week. They had to give up and put these studies with the discards. The breakdowns on the studies were not in basic elements.

MISCELLANEOUS STANDARDS

Do you see what I mean by detailing the study? That is a vital step in data preparation. And if it is done correctly for the productive elements, it can and must be done for the miscellaneous elements. If you go along with me on recording the non-standard elements, your next question is, "What do I do with them?" You should summarize them in standard data form for ready reference. Then, you will have standard times to cover practically every condition that may occur. How to arrange and economically handle standard times such as these is the subject we are leading up to in this book.

Here, I want to emphasize the necessity for measuring and compensating for the extras. The President of a small company puts his finger right on the crux of the matter when he said, "Dyer Engineers is the third consulting outfit that has been in this plant, but the first one that has reduced costs." What he did not say was that our predecessors had measured all the easy jobs and had left the difficult ones unmeasured. The result was that the employees went to work on incentive and made themselves substantial premiums. But they took their relaxation on the non-standard jobs.

Coming back to the irregular conditions, standard data must be arranged so that standards can be set quickly for new conditions. This method of solution is important if we are to avoid either of two poor choices. The first is the loss of opportunity to earn premium. The second is even worse, namely, the tendency to guarantee past earned rates for the "daywork" time.

TEMPORARY STANDARDS

Assuming we are equipped to cover the irregular conditions, the standards set to cover them should not be called "temporary." The use of the word "temporary" is a mistake. Many shop men fear "temporary rates." They feel that the times will be reduced as soon as the timestudy man finds out how much can be earned on them. Obviously, as a rule, the type of "rate setter" guilty of such subterfuge *doesn't* find out because the production is restricted. The effect of "temporary rates" is important enough to be mentioned in "Guiding Principles for Wage Incentive Plants."[1] The statement made in this connection is as follows:

> Number 10: The practice of setting a temporary standard in new plants or on new operations (because of the desires of both management and labor to have incentive work before the permanent standards can be set) should be kept to a minimum. It should in any event be clear to all that the standards are temporary and for a reasonably short period only.

Some thoroughly conscientious timestudy men set "temporary rates." They do so in order to create the opportunities for incentive earnings while working conditions are sub-normal. The conditions in the shop are temporary perhaps in terms of some mental definition of normal. But they will be changed again and again as progress is made, or as slippage occurs. To keep the work on incentive, they may build up boxes full of "temporary rates." They set dozens for many operations. This approach is not a good solution.

To solve the problem, we should take the point of view that only one standard is to be set for the normal conditions that exist for the plant. Then separate allowance standards should be set as conditions change away from normal. With this method of handling, there is no reason for using the term "temporary." The expense part of the standard should always remain separate from the basic standard, because it is indirect labor. It is indirect labor because there are no extra pieces produced for the extra work. Since it is indirect or overhead labor, it cannot carry overhead costs. This phase of work measurement has an important bearing on overhead ratios as we discussed them in Chap. 3.

Separate allowances must be made for the differences between actual and normal working conditions. Otherwise, the differences will affect take-home pay. Variations in the amount of work to be done and in delay times that interfere with production are two complexities that cannot be fairly averaged into the standards. Average allowance would serve only to cut the variations in half. Therefore, it should be emphasized that *incentive plans cannot be simple and, at the same time, be fair.*

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[1] "Wage Incentive Plans," Management Consultant Division, War Production Board, October, 1944.

SETUP STANDARDS

Going on with the irregularities, we can get some pointers from the approach used to measure setup. Too often, we overlook the measurement of this work. Granted that it is complicated by many variables, it is important that we measure it, particularly when the operator makes his own setup. You readily understand what happens when daywork time is mixed with incentive time. The operator has the natural inclination to take his relaxation on the jobs that are not measured. That is one detail only. The more important one is the necessity for factual information about setup costs. Setups must be measured when an industry is engaged in manufacturing to customer specifications or in small lots. In instances of this sort, the setup may be in the neighborhood of 30 per cent of the work expended on an order.

To get data for setup standards, we have to make it our business to study the setup along with the regular operation. This is to accomplish two results:

1. We want to prepare the standard data for setup so that it can be applied at the same time that the standards for the operation are put into effect.
2. We should time the setup preceding the operation along with it, because so much of the true setup actually takes place during the first several pieces made.

Perhaps we have avoided establishing setup standards because we do not understand how to apply them. Part of the trouble is that the setup is variable. That means we cannot say that the standard will be a fixed amount. But this difficulty can be solved if we can find another way to apply the standards.

CHECKER-SET STANDARDS

Standards for setup should be determined in the same way that they are for variations in working conditions. They must be set according to the job that is done. As a matter of fact, one of the best ways to handle these is to establish them on the floor according to the work required at the time. To do this, you can use a roving checker who has been trained to act as a junior timestudy man. He should be trained to set standards according to the work required to make the particular setup.

The setup is defined here as including the tear down also. It is sure to vary for any given job according to the condition of the machine as it was left from the previous operations. For example, on a turret lathe, suppose the previous job utilized a chuck. If the new job is done in the same size chuck, no change will be required in this part of the equipment. In contrast, if the previous job was done on a faceplate, then it would be necessary to remove the faceplate and put on a chuck before the new job could be started.

The problem of setting standards for setups involves basically a consideration of all the variations that are likely to be encountered. Then we must establish correct standards for the setup elements. These must include time standards for all the different kinds of accessories that may be added to the machine arrangement. Timestudies must supply two standards for each element of equipment. These are for the tear down and the setup of each of the accessories.

In the first step toward applying them, certain element standards can be combined. One example is that just mentioned. "Take off the faceplate" and "Put on the chuck" should be combined. Several such groups of elements are necessary in this instance. The point is that some device will be used to hold the piece. If one accessory is taken off, another will be put on. Therefore, you should make up all the probable groups of elements for ease in application. More broadly, the change-over from one arrangement to another may involve anything from a variation in a few sizes or tools to a complete re-arrangement. Consequently, any amount of change between these two extremes must be provided for.

One way to do this is illustrated in the latter chapters in the form of multi-variable charts. Briefly, you should set up all the conditions for Tear Down. At the top of the chart is the better location. My reason for suggesting the short side of the page is that the Tear Down conditions are the simpler ones. All the conditions should be so arranged that graphical tracing through them will bring you to the total for one complete combination, the total being the full standard for the Tear Down. All these standards would appear in the bottom row, below the conditions but above the chart. Then set up the same arrangements for the Setup. These would be placed along the left side of the sheet. Again the total standards for the combinations would show just to the right of these groupings. These separated totals for Tear Down and Setup are shown for two purposes. First, they can be used to allow for an incomplete change-over. Second, they are necessary to compile the total of Tear Down plus Setup. A simple illustration of the result is found on page 131 in "Timestudy for Cost Control."[1]

GETTING THE COUNT

If you will analyze carefully what you have just read you will come up with two ideas. The first is a picture of how to wrap up the data so as to attain relative ease in rapid application. This is what we want to spell out in the later chapters. But in addition, you should see a principle for applying standards. I refer to the use of an eye-witness checker. This is the missing link. It makes possible the application of standards to all kinds of work that cannot be prescribed on Operation Sheets.

Let's develop this application method from another side. Then we can go on with charting. To make the point, suppose we take an example. We find it in Shipping, Receiving, Stock Room, Order Department, and Branch Office, to name several. We can set the standards all right, if we have become skilled in standard data preparation. But you may ask, "How do you apply them?" What you should ask is, "How do we get the count?"

That is not so difficult. For instance, in Shipping you get a slip for everything. It is an official document. It is equivalent to a bank check. That slip will become an invoice. The customer will either send a check or send back the material. The slip is almost the best count you can get. The only problem then, is to tie your standards into the slips. Find out what work results because of the shipping ticket. Maybe there are several kinds. Maybe there are variations for each kind. But those problems are relatively easy to solve.

TALLY SHEET

This sort of solution should not be allowed to bog down because of clerical weight. We can't afford to worry with job tickets. They cost too much. My first answer to this problem is, "Job costs are not worth the paper they are written on. What you need for control purposes are normal costs." I prefer the term "normal costs" because standard costs should be based on a normal volume.

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[1] Carroll, Phil, "Timestudy for Cost Control," 2d ed., McGraw-Hill Book Company, Inc., New York, 1943.

You approach normal costs when you calculate incentive premiums over the full day. That is my method. With premium figured daily, it is impractical to get a job or operation cost as a segment of a day. Any one of the job performances may fall below standard. I find the first and last jobs of the day are apt to be under. This is due to (1) the warming-up period at the start and (2) the anticipation of the day's end. In some cases, this trailing off toward quitting time might be a looking forward to the evening's amusements.

To see this more clearly, cut up the day with a hundred little jobs. Even though this makes an impossible situation with job tickets, it is only a matter of accounting system. Anyhow, it suggests the use of a tally sheet. Under some conditions, you can put all the different standards down the side of the man's, or group's, time sheet. Across the sheet, you can put columns or other spacings. The columns can be headed with specific titles. They can be left blank so that jobs, job types, or other identifications can be written in. My recommendation is to label the columns when the variety is a small number. Leave them open when the variety is great. One sample can be seen on page 227 of "Timestudy for Cost Control."[1]

GETTING MORE DONE

The discussion in this chapter serves only to outline a few steps that may lead to the use of some better methods. It grows out of experiences that show we spend too great a per cent of our timestudy effort in "rate setting." Not enough thought has been given to the ultimate use we can make of our time. It appears as though much greater effort has been expended in perfecting the operation than in preparing the proper setup. A well-rounded job requires that both be done completely. Remembering that the standard data method involves both setup and operation, you should not neglect either part. The total cost of your standards may be in excess of an economical amount. The lowest cost consistent with quality is what we are after. The approach we use on work we measure must be applied in our own back yard. Unless we analyze and improve our own methods, we never will get the opportunity to provide fair incentives for the people now on "daywork."

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[1] Carroll, Phil, "Timestudy for Cost Control," 2d ed., McGraw-Hill Book Company, Inc., New York, 1943.

CHAPTER 7

FORMS OF STANDARD DATA

Timestudy men spend a great deal of their energies in efforts to improve processing time. Every effort in this direction tends to reduce the denominator over which overhead must be spread. The result is that the percentage of timestudy as an expense is further increased. Consequently, every so often, timestudy men are reminded that they are part of overhead.

From another point of view, the timestudy man wants to look at his own methods because of the necessity for "paying his way." The so-called savings made by the introduction of an incentive plan are soon lost sight of in the course of business progress. Much of the gain is passed along to the consumer in the way of reduced prices. It is not long before most of the timestudy effort is in reality a maintenance expense. Of course, if maintenance is neglected, the incentive plan will break down, just the same as if it were a machine. Therefore, proper maintenance is necessary. However, it is highly desirable to have the expense as low as it can be consistent with good workmanship.

The foregoing remarks are intended to emphasize the fact that a concern cannot afford to keep on paying for the same old methods. The company will be left behind by its competition if it does not continue to improve methods. The same can be said for the Standards Department. It should understand the necessity for improving its own methods and reducing its own costs.

Some timestudy men will argue that their jobs cannot be improved. On the other hand, those same men would be indignant with a supervisor who argued that a proposed change in method "won't work." The timestudy man tells the supervisor with considerable emphasis that "any job can be improved." This applies to any kind of work and certainly to timestudy. Much can be done to improve timestudy methods as carried on in the average plant.

In particular, considerable improvement can be made in the method of setting standards from data by the use of more efficient arrangements. At the same time, it must be kept in mind that the same rules apply here as in all method study. It must be remembered that every suggested improvement has disadvantages as well as advantages. Considering only cost, it is necessary to determine when the savings to be gained will exceed the costs to install and operate the improvement. In the main, the answer to the problem is largely determined by the quantity manufactured or the yearly activity of the operation involved.

CHOICE OF SETUP

Data, like tools, take many forms. Some are better than others. Like tools, their costs are affected by the degree of perfection. At the same time, there appear to be almost as many varieties of so-called standard data as there are Standards Departments. A certain variety is essential to secure the maximum economies for a given set of conditions. But some of the forms observed were the result of incomplete analysis as contrasted with informed selection.

Perhaps an analogy will help to develop our theme. The choice of data form is like the question that comes up every day in the shop with regard to lathe operations. Many parts that are to be machined can be made on an engine lathe, turret lathe, semi- or full-automatic. There are very important costs that should be considered. But in the average shop, the machine to use is often determined by comparing the Setup with the Piece Time. When the quantity multiplied by the operation Standard plus the Setup is the least total amount, it is assumed to indicate the proper method to use.

In general, we expect the operation Standard to vary inversely with the type of Setup. To improve the Piece Time, usually we have to spend more time on the Setup. Timestudy men and methods engineers know that many improvements in operation can be made only by spending money for better gadgets. Oftentimes, however, they completely forget that there are other costs greater than labor cost. As a result of concentration on timestudy and methods work, many men limit their thinking to time savings. Sometimes they unwittingly increase overhead expenses out of all reasonable proportions to the reductions made in direct cost.

CREATING MONUMENTS

That may seem to be beside the point, but it has a bearing on standard data preparation. It is injected here to caution, if possible, against a tendency to create standard data works of art—monuments of engineering achievement. The timestudy analyst has the same possibilities for exercising his creative talents in this field as in that of methods improvement. Within his own department, however, there is not the controlling resistance to change that the shop uses to dampen his efforts. There are no tool costs and similar expense reportings to remind him if he goes out of bounds.

So the situation is approximately this. We have basic standard data ready to be arranged for everyday use, several general forms to use in presenting it, and the timestudy analyst all set to outdo himself in creating a monument to his name. No sarcasm is implied in the term monument. The more it costs in efficient preparation, the less will be the time required to set each standard. But we do not perform all the lathe work on an automatic. We attempt to determine the most economical method for the quantity involved.

The same thinking must be used when choosing the form for basic data. The factors are the same. First, there is a cost of Setup—the preparation of the Working Data. Second, the operation Standard is analogous to the standard setting time. The quantity is the probable number of standards to be set before a revision is required in the Working Data.

Reducing the time required to set the standard is much more than an engineering discussion, as it affects timestudy costs. It is far more important to the attainment of our objective than you may realize. It is like the price of a product as related to the number of consumers who will buy at a given price. That is like talking about an automobile for every family. The number of families that can have one increases as the cost comes down further. It may never get low enough. But each reduction in price will make the automobile available to a larger number of people.

The same arithmetic applies in standard setting. The further down the cost of each can be brought, the more widespread can be the application of direct incentives. Cost is an important factor controlling how far you can go in economically applying measurement for incentives. The subject is important not only in connection with certain direct operations, but also with the many indirect operations not yet measured. The vital consideration here is that the same opportunities to earn higher wages for greater effort should be given to all those working in a given plant. Then also, there is a huge number of small plants where incentive is said to be impractical because of its cost. The last census reported that 91 per cent of the industrial plants in the United States had less than five hundred employees.

The situation may be emphasized by using an illustration. We are aware of the fact that the price of a given raw material, like coal, oil, iron, or gold, is increased by demand for more output. Some sources of material are put into operation only when the work can be done with profit. For example, certain mines are called "marginal" because they are put into operation or shut down according to the price the output will bring. In the same way, certain applications of incentive may be unprofitable. Perhaps, the determination is made in terms of timestudy methods that are too costly. It follows then that if the costs of these methods are reduced, the benefits of incentive can be extended.

TIME AND ERROR

The timestudy man should be thoroughly familiar with the methods of construction and uses of all the general forms for presenting standard data. With this knowledge, he can go more directly to the most economical solution for his problem. Just as in the shop, his objective is to gain the lowest total cost of standard setting considering both the setup and the operation times. The setup itself is an important consideration because, as is readily recognized, one setup on a given machine for a particular operation can be made much more efficient than another setup for the same conditions.

Efficiency must be sought in three directions. One is in the form itself. This has to do with how rapidly standards can be set correctly. The second consideration is the amount of clerical work required—writing and computing. The most important factor concerns the amount of mental effort required to think correctly while applying the working data. The time involved in the mental operations is influenced greatly by the layout of the working data and the clarity of its specifications. The specifications govern the application of the standard times and should be arranged to eliminate decisions and choices. When it is necessary to interpret the specifications, extra time is required and errors are introduced.

CLERICAL EFFORT

Beyond the errors that may result from interpretation are those arising from clerical mistakes. More likelihood of error may be introduced by the particular form used than by another that might have been substituted. Besides, when considering the form for presenting standard data, we must study it for its effect upon time.

The time is altered substantially as the amount of writing necessary to set a standard is reduced to a minimum. The ideal result is accomplished when the form can be arranged for checking instead of writing. A check mark or a circle can be made to clearly indicate the factors considered in determining the proper variable time and the standard itself. Remember also that all writing carries with it the probability of making some errors. This is especially true when noting the specifications that determine the variable times. In addition, there is the opportunity in any copy work for error in placement of decimal points. Therefore, every practical effort should be made to arrange the data in a form that will cut clerical work to a minimum.

LISTED DATA

Speed, accuracy, and clerical effort all enter into the proper choice of the data form. Each form has both advantages and disadvantages. The simplest form of tabular data is a listing of the elements found in a given type of work. This is only a special arrangement of basic elements copied from the Comparison Sheet used to build up the data. Certain combinations are made in this listing, such as adding opposites together. By opposites are meant those elements that are sure to follow each other. Examples are "Pick Up" and "Lay Aside." On a drill press, "Raise the Spindle" is bound to follow "Lower the Spindle." These and similar combinations are made as the first step.

To use data in the listed form, the standard setter must make a mental motion study. He reads each element description in turn and selects those to be allowed. Then he determines how many times each will be required. Finally he, or someone else, makes the extensions and adds to obtain the total. Most of the time consumed is required for the mental process of deciding what elements are to be allowed. Since considerable time is taken relatively, this form of data is expensive to use. Also, it permits some mistakes of omission and commission. If the standard setter assumes certain elements are required that will not be used, the standard will be loose. As you know, errors of this kind probably will not be heard from. On the other hand, if required elements have been left out, it is likely that the standard will be called tight. Upon review, it will be raised.

CURVE

Listing of data is convenient for constant elements. But variables present most of the problems of arrangement. Ordinarily, curves are developed in the process of analyzing the variables found in the standard data. While they may be redrawn for use in standard setting, it might be said that the costs of the curves are zero because they exist at the time when the setting of standards can be started. The curve has several disadvantages, however, in that it is interpreted with difficulty and error. Besides, it is mysterious to operators and supervisors.

EQUATION

Since most data consists of both constants and variables, we have to consider ways to combine them. One of the ways to combine curves is through the medium of their equations. These are often set up as a subsequent step. To the equations of the curves, constant elements and other factors can be added to approach the algebraic expression representing the total time to be allowed. In this form it is often called a formula. Developing equations from curves takes time, and therefore this method is somewhat more expensive. Calculating the standard time from a formula is one of the most expensive processes of standards computation. Another disadvantage is that the formula is very apt to be even more mysterious to the shop man than the curve itself.

CHART

Another way to set up variables and constants is by means of charts. Simple two-variable charts may be made directly from curves, or from their equations. By either process, additional time is consumed, and, therefore, the chart is somewhat more expensive to prepare. However, charts are not subject to the same errors of interpretation as the curves. They are not nearly as puzzling as a formula to those who are unfamiliar with algebraic signs. The chart is more readily understood by those to whom it will be explained.

NOMOGRAPH

Another form for combining is the line diagram called a nomograph or an alignment chart. This form of chart is more like a group of curves than a table. It is a line diagram arranged to perform algebraic functions by means of a straight edge placed across it. In general, the scales on the nomograph must be laid out graphically. The result is that certain small errors are introduced. Even so, the nomograph offers another means for combining several curves or charts, together with constant times and factors. Naturally, the nomograph would be even more mysterious than one or more curves. Part of this difficulty arises from the fact that it is not often used. Therefore, the average shop man is not acquainted with the nomograph.

FAMILY OF CURVES

Like the nomograph, the family of curves can be used to combine standard times for several variables, constants, and factors. As a rule, they are less expensive to construct than nomographs designed to accomplish the same result. While they are easier to explain and to understand than the nomograph, they do appear to be more complex.

MULTI-VARIABLE CHART

In general, charts are easier to explain. And when there are many factors used in setting standards, a chart that will do the job will contain several variables. "Multi-variable" is a term used to indicate a chart that combines more than two variables. Generally speaking, it is the most expensive of all forms to prepare. However, because it is a combination of tabulated results, it is comparatively simple to understand and explain.

Charts are not as accurate as curves because the number of standards possible of determination from a curve is greatly reduced when set up in tabular form. Many of the possible answers are eliminated because the curve is read at intervals. This is not a drawback, inasmuch as absolute accuracy is not as important to us as coverage. Of course, the standard data has to be right. That is apparent because the same element time standards are used again and again wherever the same work occurs. But it is like anything else that is expected to function properly for a long time. It has to be built up soundly. It must be thoroughly and specifically defined. But most emphatically, it must be revised and kept strictly up to date.

Charts are advantageous also in that they lend themselves to arrangements that lessen clerical effort. Often, they can be duplicated on 8½- by 11-inch paper. Usually, the standard can be set by drawing circles around the grouped element times that apply. The clerical work can be limited almost to simply filling in part number, specifications, and other details to identify the standard determined on the form.

BETTER TOOLS

The foregoing are but thumbnail sketches of the six commonly used forms of working data. Each will be developed further. One or more chapters will be given to the construction and use of each form. Each has its useful applications. We can make of them a kit of timestudy production tools.

In the shop, we often make remarkable increases in production by introducing jigs and fixtures in processes that are already considered to be very efficient. So it is with devices that we can use to expedite the application of standard data. We can arrange it in various forms. Some are more efficient than others. Here is where the question of practicality of incentive measurement may be determined from wholly different conditions. For instance, it may be that with one form of data the cost of standard setting is too high. Another form may so reduce the cost per standard as to make incentive coverage entirely practical in operations that are often neglected.

That gets us on to the main theme of this book—charting standard time data. Charting is the form of the setup. It is the tool or layout. Its importance lies in its applications as a cost-reducing device. In different ways and degrees, charting can be used to greatly reduce the cost per standard. As a result, incentives can be extended economically to many operations now left unmeasured. Opportunities to increase earnings can be provided to many people now "putting in time." Here, the statement that "we want to do the greatest good for the greatest number" applies most emphatically. We must not think solely of how we can reduce the cost of timestudy efforts. The important consideration is how to extend the benefits of incentive to the fullest coverage for all in the organization.

CHAPTER 8

STANDARDS FOR CURVE DRAWING

Curves are very important tools in timestudy. They are used to analyze element data and to determine relationships between variables of time and dimensional factors. They are indispensable in the preparation of standard data.

Curves may be straight or curved lines. They may be constructed singly or in multiple. They represent gradual progressions in the relation of one variable to another. Usually, one of the variables is Standard Time. Most timestudy curves are drawn to measure the effect on standard time caused by some dimensional factor. The other variable is therefore Dimension.

In the general case, the curves result from the plotting of timestudy data. Each plotted point is a time value. Ordinarily, it is a standard time resulting from a timestudy that has been normalized, with relaxation added.

Incidentally, it is the standard time for an element that would have been allowed if an operation "rate" had been set from the individual timestudy. Only normalized or standard times should be plotted. Relaxation factors can be omitted, although my personal preference is to include them. Actual times cannot logically be compared. Consequently, it is not only a waste of time to plot actuals but, more importantly, it is very apt to lead to wrong conclusions.

When both conversions are included as standard procedure, mistakes are less likely to happen. By working always with the relaxation included, it cannot be overlooked when some part of the data is used in another operation or department. Also, it is less confusing to explain. It may appear like sleight of hand to the foreman or the mechanic if you add on or take off percentages during an explanation of standards. So we might start off with one rule by saying that

1. *Points plotted on curves should be standard times all converted to the same normal rating with proper relaxation factors included.*

CURVE LAYOUT

To set up a curve, we need cross-section paper. The usual type has 20 squares to the inch. The preferred paper size is 8½ by 11 inches, and it is punched for standard three-ring binding.

But you would be surprised at the number of different ways timestudy men can use to lay out the same kind of paper. Some place the dimension factor on the vertical scale. Some use only part of the scales available. Some start the scales so that 0 is way off the page. Consequently, it seems a good idea to give some simple rules for curve drawing. A good reference pamphlet on the subject is "Engineering and Scientific Graphs for Publications."[1]

In this authoritative pamphlet, it says that the independent variable should increase from left to right. In timestudy language that means the Dimension scale should be placed along the bottom of the cross-section paper. The dependent variable should read from bottom to top. That means the Standard Time scale should be placed along the vertical edge of the paper. (See Fig. 7.)

To summarize, we might insert a second and important rule:

2. *Standard Time is placed along the vertical scale of a curve and Dimension on the horizontal scale.*

For appearance' sake, the scales should be written in along the full distance of the page. For practical reasons, the scales should be chosen so that they spread out the full distance. This latter rule should be interpreted to mean you should use scales that are easily understood. Usually, some multiple of 5 is best with 20-square paper. The divisions of the scale should correspond with the heavy lines on the cross-section paper.

Scales made up of odd divisions are inefficient to use. The standard setter has to count out the odd divisions each time to plot a point correctly or to read the final curve. Such scales are often read incorrectly. Errors are created.

The scales selected should extend from 0 to the maximum of the range anticipated. This should accomplish two things. First, it should magnify the results to the full extent permitted by the paper size. Second, it should place the curve about on the diagonal of the page. That will approach a 45-degree angle and approximate the best analytical relation between the two variables. Examples of correct and incorrect scale layout are shown on Fig. 8.

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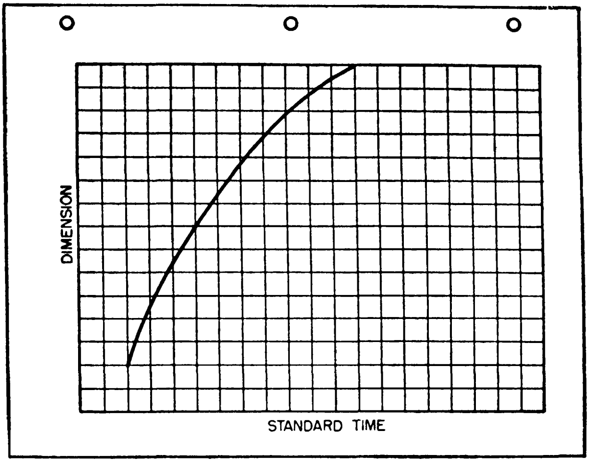
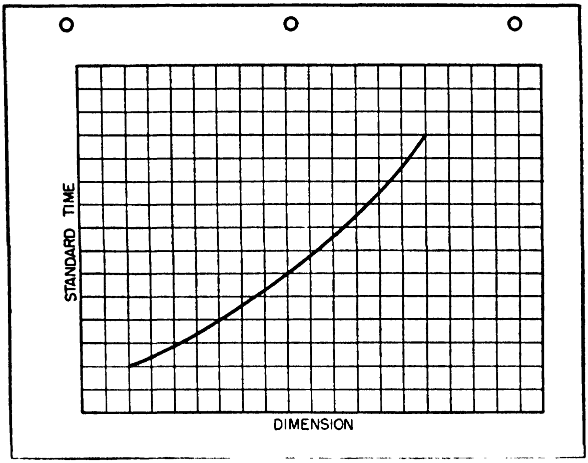
[1] ASA Z15.3, American Society of Mechanical Engineers, New York, 1943.

3. *Choose scales that start with 0 and place the extremes of the ranges as near the ends as possible, without requiring the use of odd divisions of the cross-section paper.*

One other fundamental detail should be emphasized. All scales should start at 0. Some may not agree that this is important.



(*a*) Not correct.

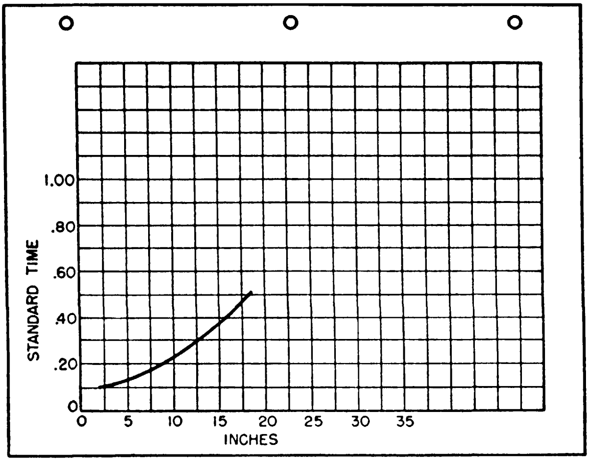


(*b*) Correct.

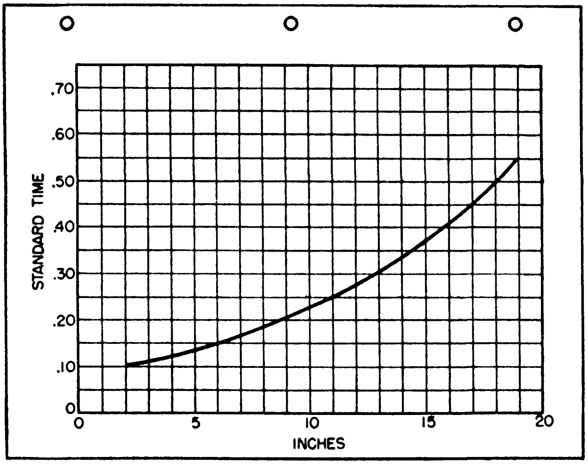
FIG. 7. Curves should be laid out with the Dimension Factor along the horizontal scale and Standard Time on the vertical scale.

It is, however, because curves drawn with scales that begin with 0–0 more correctly portray the constants that are included in most variable element standards.

The point involved has more to do in aiding correct analysis than anything else. Curves show their right proportions when



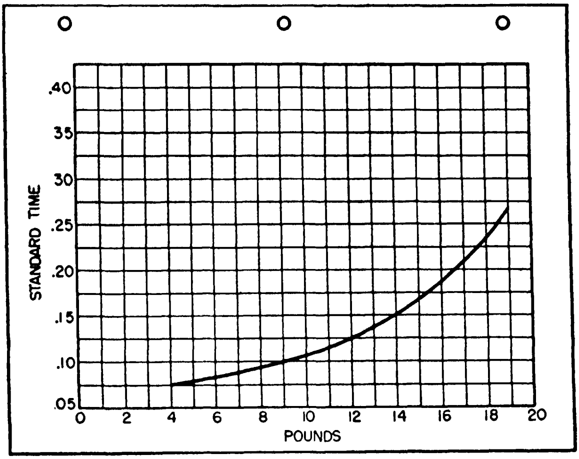
(*a*) Not correct.



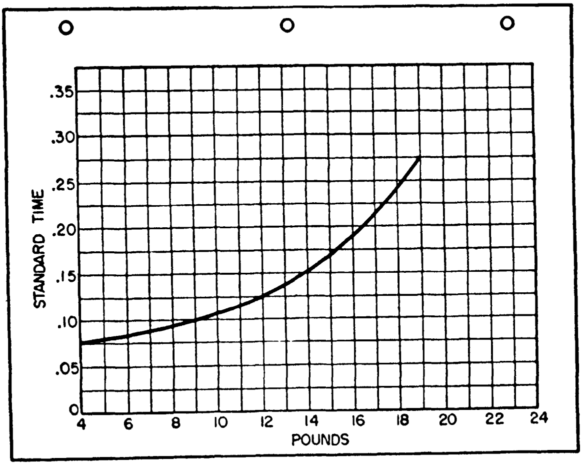
(*b*) Correct.

FIG. 8. Two typical mistakes are illustrated in Curve (*a*). The important one is that the scales chosen have too great a range. This is emphasized by the second mistake—the scales extend only part way along the edges of the page.

plotted from 0–0. The inherent constant is correctly portrayed in relation to the slope. The effects of distortion caused by incorrect plotting will be seen in a study of Fig. 9.



(*a*) Not correct.



(*b*) Not correct.

FIG. 9. Two curves drawn to illustrate the disproportionate size of the inherent constant that results when scales do not start at 0–0.

In Fig. 9*c* the scales are laid out correctly. Both start with 0. Figure 9*a* has omitted from it the length from 0 to .05. As a result, the inherent constant seems to be much smaller. The reverse appearance could have been shown by an example combining the omissions from both 9*a* and 9*b*. With these examples to emphasize this defect in curve plotting, we can set down a fourth rule.

4. *Start the Standard Time and the Dimension scales with 0–0 in the lower left-hand corner of the curve.*

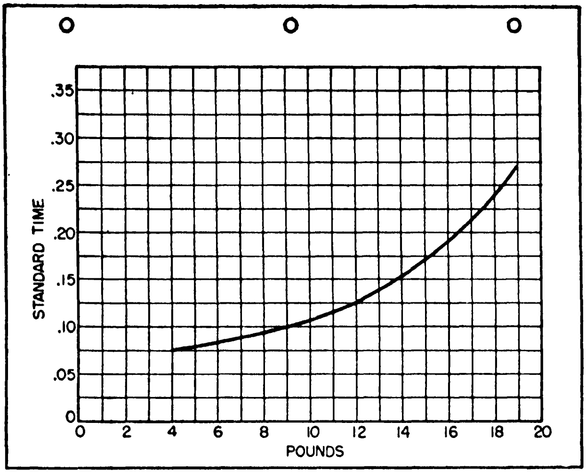


FIG. 9. (*Continued*) (c) Correct. Example (*a*) makes the constant standard time appear smaller than it is. Example (*b*) indicates a relatively larger constant.

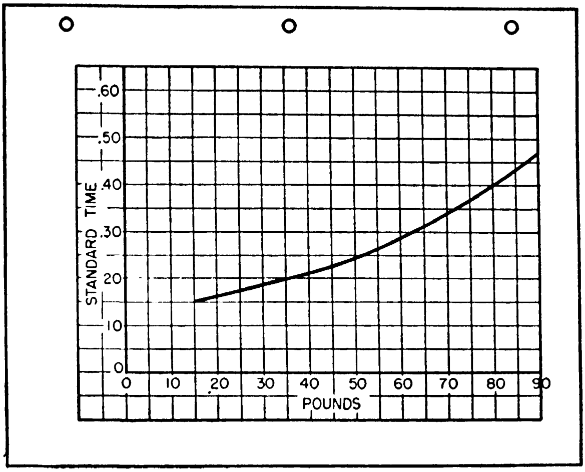
DESCRIPTIVE DETAILS

Scales should be placed outside the cross-section part of the sheet in the blank margins. The descriptions or names of the variable factors should be printed outside also, between the scales and the margins of the paper (Fig. 10). Lettering of any vertical scale description should read from bottom to top as shown on all "correct" curves in this chapter.

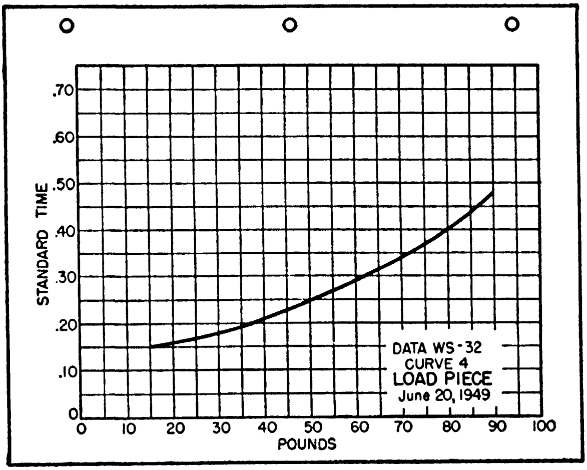
5. *Letter the scales outside the cross-section part of the curve paper.*

CURVE HEADING

Each curve should have on it several notes to clearly identify it. Descriptive notations can best be arranged for by specially designed headings at the top of the sheet (Fig. 11). This can be done quite inexpensively when several hundred sheets of cross-section paper will be used. One way to make up standardized cross-section paper is by means of the photo-offset process. To prepare,



(*a*) Not correct.



(*b*) Correct.

FIG. 10. Scale figures and descriptions should be placed in the margins outside the cross-section paper. Curves should be fully identified with Date, Element description, and Data designation. Curve Number is desirable when there are several in the data.

make a dummy by pasting together the design features suitable for the Standards Department. The cross-section paper chosen would ordinarily be 20 squares per inch. However, one of the most skilled men I know prefers millimeter ruling.

The selected type of cross-section ruling should be pasted on a larger piece of white cardboard. It should be located to allow for proper margins. Then the heading captions should be neatly lettered and other identifying notes like the company name should be added. These may be printed on strips of paper if the plant has equipment available. The lettering should be mounted on the cardboard dummy in proper alignment with the cross-section paper.

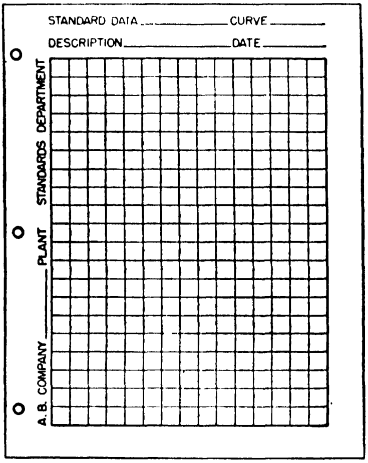

STANDARD DATA _____ CURVE _____
DESCRIPTION _____ DATE _____
A.B. COMPANY _____ PLANT STANDARDS DEPARTMENT

FIG. 11. Standardized curve headings may be printed on the cross-section paper when quantity to be used warrants it.

Next come the border lines. First of all, remember that the dummy is oversize. It is to be reduced photographically to 8½ by 11 inches. You can spot the approximate location of the top and bottom margin lines. Suppose the space allotted measures 14½ inches. For this length, the width must be 14.5/11 times 8.5, or 11.2 inches. Allowing 1 inch for the margin where Dimension scale and lettering will go, provides about ¾ inch when reduced. Measuring from this line across a width of 11.2 inches will locate the paper edge on the binding margin. This should be ample. An inch and a half after reduction is about right as a margin. If the over-all width thus determined does not permit ample margins, then approach the border lining from width as a starter to determine length.

Having finally located the margin lines, there is another detail that is desirable to include. The detail is a border line all around the completed cross-section paper. The purpose is to get back copies from Blueprinting that somewhat resemble an 8½- by 11-inch page. So if you are accustomed to blueprints trimmed on the bias, put an ink border line all around the dummy. Then draw pencil lines outside that border about ¼ inch away from it for the photo-offset printer to work to for paper size when photographing the dummy.

Black printing is cheaper, of course, but it is not recommended. Plottings stand out much better on colored rulings. Orange or green printing provides better "working conditions" for the analyst.

The details to go on a curve will vary with plant requirements but several are essential. They are, first and most important, the *Date*, second, the *Element* description, and third, the *Data* designation. This latter is often a code number. Curve *Number* is very useful for reference purposes if the data includes more than one curve. But don't forget the *Date.*

6. *Put the Date on each curve, together with Element description and other positive identification.*

CURVE LABELS

Frequently, there are several curves on one sheet. This happens because many of the variables being analyzed are actually families of curves. Consequently, each curve must be distinguished from the others.

In plotting, each should be designated by one specific symbol or color. Symbols should be used if the curves are to be reproduced. Obviously, colors will not show up in blueprinting. Color designations are usually satisfactory, however, because curves are not often reproduced. The reasons why will be gone into later on when we discuss charting. Each curve should be labeled. The titles should be placed close to the curves so there can be no mistake in correct identification. Arrows can be drawn from labels to curves, if necessary, to avoid confusion.

Draughting rules call for horizontal lettering of labels. This cannot always be done with timestudy curves. Often, they come too close together. Often, also, the only labels necessary are figures to show dimensional factors. These may be printed one space away from the curves and just above or at the ends. (See Fig. 12.) When they are printed at the ends, which I recommend as the better location, there is less confusion. However, when curves are used for standard setting, central labeling is preferred. Labels directly in front of the user will prevent some mistakes. Labels at the ends require too much eye travel. Mistakes are easily made especially when curves are close together.

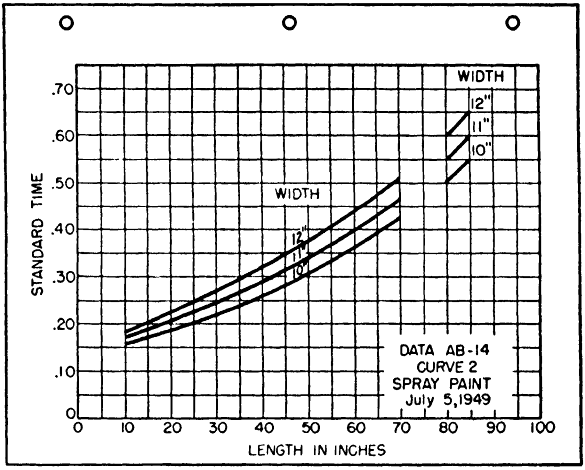


FIG. 12. Curve labels may be printed at the ends of the curve, or near the center.

7. *Use specific symbols to distinguish individual curves and clearly label each to identify it.*

PLACING THE CURVES

It seems out of order to label the curves before they are drawn in. But the symbols and labels go together so they were discussed under the same heading.

In between the assigning of symbols for plotting and the labeling of completed curves comes the drawing in. The curves to be drawn may be straight lines or curves. Straight lines are easy to draw. Maybe that is why so many are drawn straight when they should be curved. In all fairness, however, it should be stated that there are many instances where the straight line is quite correct. These cases occur where the range of the variable is so short that there is no significant difference between a curve and a straight line.

To locate a straight line, you may use either of two methods. The Method of Least Squares is advocated by some. It is a mathematically accurate way to locate a straight line through a series of points. This method is described in Chap. 11, which deals with equations.

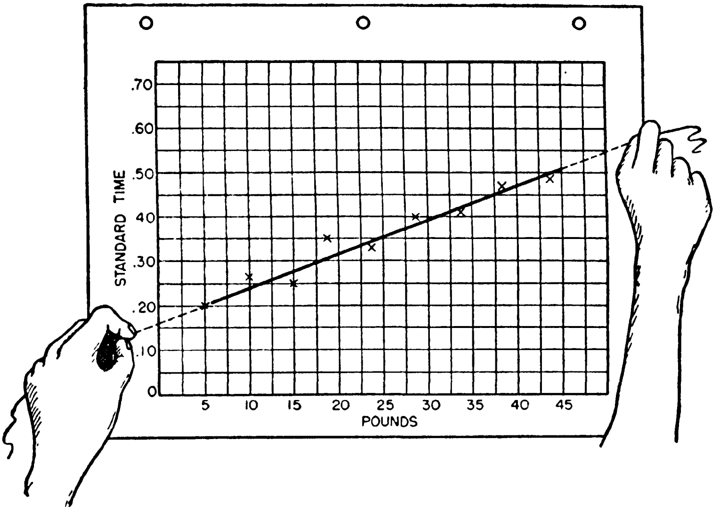


FIG. 13. You may stretch a rubber band or string through a series of points to locate a straight line. This method is preferred for its ease of analytical review.

My personal preference is to locate the line by means of a stretched rubber band (Fig. 13). This method is not scientific. But I think it is more correct than the mathematically accurate method for several reasons. First, we are trying to determine fair standards. What we want, therefore, is a line representative of the variable. This may require giving more weight to some points than others. For illustration, standards (points) set by the skilled timestudy men should be more significant than those set by other observers whose skill and training are not up to specifications.

Straight-line curves are truly representative of mathematical solutions. Machine time is the most common example. Such lines can often be located with two points. It is a good idea to spot at least one other point near the center, just to be sure. It might be a curve. Also, if the three points fail to line up, you may have made a mistake in calculating any one of the three. So if you are not positive of your mathematics, locate several points. When you are all set, you can draw the lines with a straight edge. Curved lines are more difficult. And most timestudy curves are curved. They curve upward at an increasing rate. At the extreme outer range of the variable, the curve begins to point skyward.

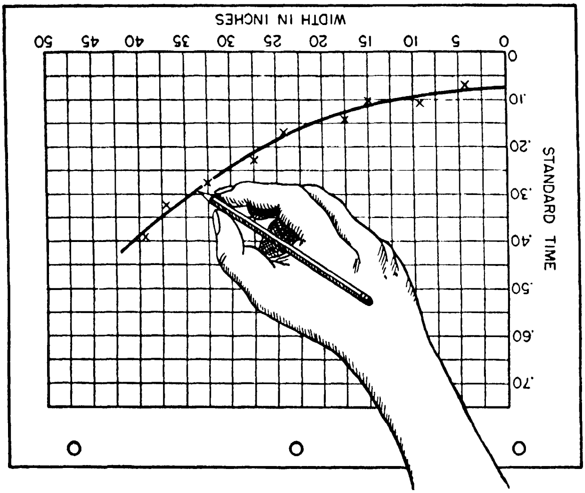


FIG. 14. A good way to sketch in a curved line is to turn the page upside down and utilize the circular motion of the arm.

Sometimes, curves can be "fitted" with an irregular curve-drawing device. These can be shaped to fit the conditions. Years ago, we used to shape ribbon solder for a ruling guide. You may use ship's curves if you have them. If you resort to French curves, look out. Fitting these is difficult. You will have better than average luck if you stop drawing any one portion of your curve before it runs out. Then find another fit and blend the two sections.[1] In doing this, I have sometimes gradually tipped the ruling pen from vertical progressively to a lesser angle as the curve was extended. Figure 14 shows a practical way to draw in a curve. It works best when done as shown. When the sheet is turned upside down, the natural circular motion of the arm helps to form the curve.

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[1] Riggleman, John R., "Graphic Methods for Presenting Business Statistics," 2d ed., p. 221, McGraw-Hill Book Company, Inc., New York, 1936.

8. *Curves are drawn to represent the correct relations between standard times and the controlling dimensions.*

CURVES FOR STANDARD SETTING

Completed curves are sometimes used for standard setting. This has some disadvantages. But there is one decided advantage. The variable data is available for use immediately after the curve is drawn. And it should be used under certain conditions. The chief application is when there are but a few standards to be set.

If curves are to be used, they should be specially drawn. Perhaps "copied" or "traced" would be more descriptive of the method. At any rate, the originals containing all the plotted points should not be used. Primarily, the basic plotted curve should be carefully preserved for use when revisions become necessary. Second, curves used by standard setters should be sharply drawn lines, completely free from plotted points.

In the reproducing process, however, you may choose to use distinctive rulings. You may draw dotted lines for certain factors. Dash lines or dot-dash lines may be used for others. If there are only three or four curves, a different ruling may be used to distinguish each one. If there are more than four lines, some pattern can be adopted.

For example, suppose curves were used for a range in width or length of 6 inches, with ½-inch sizes included. Then, you could make all the inch lines solid. The ½-inch curves could be dotted. Again, if there were four to a pattern, the inch curves could be solid. The ½-inch curves might be dashed. The ¼-inch and ¾-inch curves could be dotted.

All these little details of design are important. They save time and mistakes. They would be taken care of in short order if you tried to use the curves every day to set standards.

9. *Curves for standard setting should be drawn in dotted, dashed, and solid lines to denote dimension types, and plotted points should not be shown.*

CURVE AND CHART LETTERING

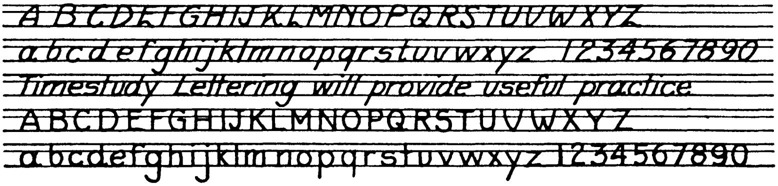
The work we turn out should be good-looking. This requires a concluding word about lettering or printing, as you may call it. Either way, we have to print letters and numbers on curves and charts. And we don't want it to bring out a comment like the one my drawing teacher made. He said, "Phil, you turn out a pretty fair drawing and then spoil it with punk lettering."

That hurt. So I began to letter instead of write. On the back of all my timestudies, everything was lettered. All my long hand reports were lettered. After a while, I could letter reasonably well, and almost as fast as I could write.

Part of the improvement came through the adoption of an easy-to-form style of lettering. It was between an engineering and an architectural type. The difference lay in using curved lines instead of straight ones in forming certain of the letters. In essence, you can tell when a line is not straight.

That reminds me of a story. Back when I was just out of high school, I worked on the railroad. One summer, my boss was "lining track." He would sit on one rail and, with spyglasses, line the track for a mile or more ahead. He had the reputation for doing the best job of lining on the whole system. One day I said, "Mr. McCullough, if it takes all that effort to get the track straight, how in the world can you line a curve?" He said, "That's easy. You can tell when track ain't straight."

So if you will try using some curves instead of straight lines, you can make certain letters much easier. For instance, A, D, K, L, and R have curves as shown in the top line of the lettering example.[1]


ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz 1234567890
Timestudy Lettering will provide useful practice
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz 1234567890

Notice another detail. The B, E, F, and similar letters are divided above the center line. Again, you can tell when the cross line is out if it is not in the center when it is supposed to be there. But if it is well above or below center, as in A or B, a small variation is not noticed.

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[1] For other pointers on drawing, see the excellent appendix in Riggleman, "Graphic Methods for Presenting Business Statistics," 2d ed., McGraw-Hill Book Company, Inc., New York, 1936.

If your lettering is not good, you should correct the difficulty. Often, all that is necessary is more practice. But you should not practice on a job that the boss is waiting to have turned in. You may spoil it. Do your practicing on something where quivering lines won't matter. If the style you are using is difficult to master, adopt an easier one. But practice until you can turn out a good-looking curve or chart, neatly lettered.

10. *Adopt an easy-to-form style of printing and practice it until your lettering is entirely acceptable.*

CHAPTER 9

TIMESTUDY DATA CURVES

With some of the construction details taken care of, we come to the engineering portion of curve plotting. For our purposes, we may define a curve as a line relation between a dimension factor and the time standards. More particularly, let us keep in mind from the outset that the curve is an analytical tool. To be an effective tool, it must be handled correctly.

The most important analytical step in curve plotting is to find out why time varies. To achieve this analysis, we plot standard element times. These standards are supposed to be correct. Remember, these are the times that would have been used if "rates" had been set from the individual timestudies. But these standard element times vary from each other for two sets of reasons — timestudy and dimensions.

EFFECT AND CAUSE

Timestudy reasons include variations in rating, watch reading, and element breakdown. These can be major causes of variation, for men not trained in data preparation. Said the other way, curve plotting is an excellent "go-no-go" gauge that makes clearly evident whether or not the observers are qualified timestudy men. My belief is that they are not qualified if their timestudy results do not line up when plotted. Something is wrong when the plotted points look like a shotgun scatter.

The "scatter" of points usually occurs with incomplete training because the watch was not read at the right breakpoint in the element. This effect often shows up with men who have been accustomed to "rate setting" from single timestudies. They can see no good reason for correct element breakdown. After all, they figure that the more details a study is divided into, the more work there is to adding it back together again.

Then there are the variations due to rating. These can be substantial because not all observers have had the training they require. Because rating can be an important variable, my recommendation is that extensive training be given in this phase to bring the variations within tolerance limits. After this has been done, the "scatter" of plottings may be caused largely by poor watch reading.

If, then, we assume that the foregoing two timestudy variations have been brought within limits, the remaining variations should be caused by dimensional factors only. Part of these could be poor timestudy if variations in work content of the elements were included. Such variations must be separated on the timestudy by finer breakdown. Where this is not possible because of the way the extras are performed, then the element descriptions should be altered to indicate non-standard conditions. Certainly, plottings would spread all over the map if they included mixtures of "horses and apples."

The remaining variations related to dimensions should be the only important ones causing a spread in plotted points. That is what we are after. The spread should depict the variables we seek to measure. At the outset however, we must keep in mind that we are working with effect. We are trying to find the cause or causes. Why do the time standards vary?

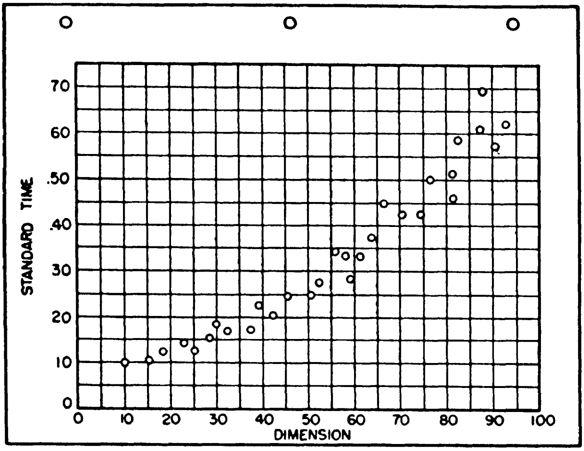
DO NOT OVER-SIMPLIFY

Usually, the reasons are multiple. Yet most of us make mistakes by trying to find simple solutions to complex problems. We must avoid this type of mistake in standard data preparation. We must assume that there are multiple causes. We must prove that a simple solution is correct before we apply it.

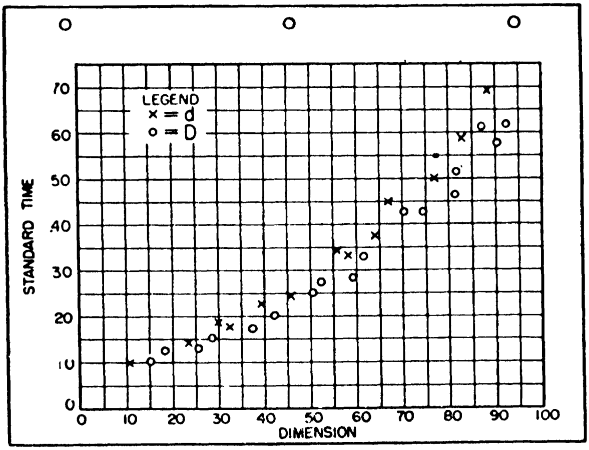
To avoid errors and to improve the effectiveness of timestudy, we should plot with symbols or colored pencils. A symbol or different color should be used to designate each suspected difference. For example, suppose we are plotting against *Area.* We suspect that *Depth* or *Thickness* might be a factor.

Then we should assign a symbol or color for each Depth and plot accordingly (Fig. 15). Then if different symbols or colors fall on the same line, to that degree our suspicions were unfounded. No harm has been done.

Many of us are contrary and can't be bothered with such refinement. We plot all our points in the same symbol. That is, the first time. But the points do not line up. At this stage, some may fudge a solution. A few will rub out the unruly points. The professional-minded man will make a fresh start. But time has been wasted and coverage lost.



(*a*) Not correct. Plotted without distinguishing symbols, these points seem to indicate the presence of only one curve.



(*b*) Correct. Distinguishing symbols clearly show that two curves are required.
FIG. 15.

Remember another influence also. Data is never finished. Changes will come later. The engineers in a going concern are sure to change designs to maintain progress or meet competition. When changes occur, they may affect the data. New studies will have to be taken. New points will be plotted. These new points may extend or expand the data. At this and successive stages, it will be most convenient to have curves that show the original analyses in designating symbols or colors. So let's make it a rule to

1. *Plot every suspected difference in an identifying symbol or color.*

WRONG DIMENSIONS

If we have plugged all the leaks mentioned thus far, the plotted points may still be all over the lot. That may result from an error in selecting the dimensional factor. We may have plotted against Volume when we should have used Area. This is an oversimplification of the previous example.

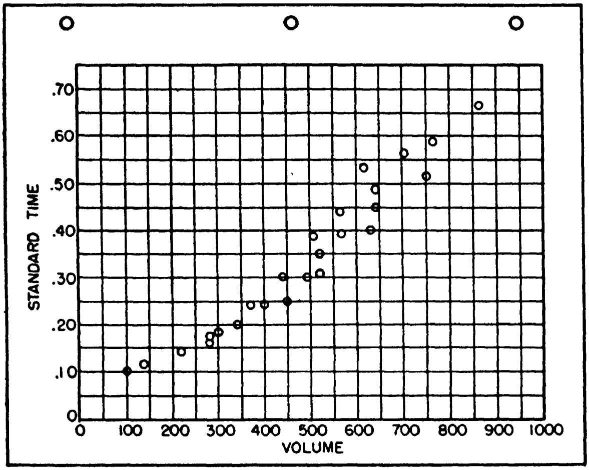
The comparative results can be seen by examining Fig. 16. The points seem to line up reasonably well on the curve in 16*a* marked Not Correct. But actually there is approximately a 35 per cent spread between the low and high points of the scatter. A line drawn through the central trend would halve this spread. Even so, the tightness or looseness would be approximately 17.5 per cent. That is too much. Such standards would be unfair.

In the example labeled Correct (16*b*), the points line up on distinct curves that show about 10 per cent separation. Averaging has been avoided. The analysis is clear for the problem as it exists. In addition, the groundwork is already laid for expansion, if new Depths are introduced.

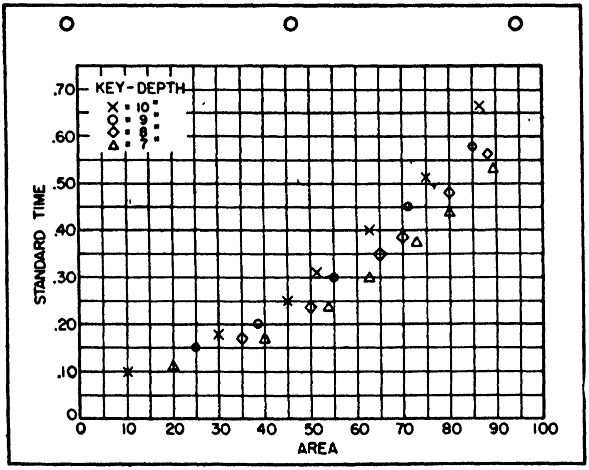
The same type of mistake is often made by using Area when Length and Width would be more correct. This is true particularly when there is a directional influence. Painting is an example. With working limited to a vertical stroke, area no longer can be a correct denominator for work measurement. True, there may be no apparent errors in large dimensions. But compare the Area with $L \times W$ analysis in the smaller ranges. Notice how the dispersion of plottings increases for the low areas in Fig. 17*a*, marked Not Correct.

What I have tried to explain here must be interpreted properly. I am talking about correct analysis. My point is that the problems are complicated, as a rule. Since they are complex, we should avoid the errors of simple solutions, of coverup averages. But analysis is different from mechanical execution. We can correctly analyze without going into complicated arithmetic. An illustration may point out the distinction and at the same time suggest a useful method.

Commonly, we have a variable depending upon circumference as the controlling dimension. The easier dimension to obtain is diameter. Therefore, you can correctly plot a curve using diameter.



(*a*) Not correct. Points seem to line up reasonably well when plotted against Volume.

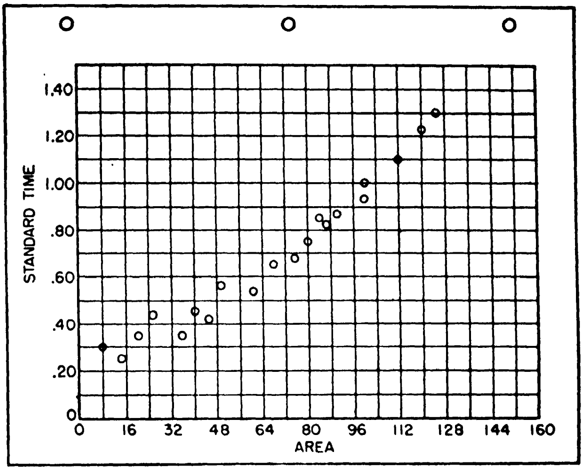


(*b*) Correct. Four distinct curves show up when the same points are plotted against Area with Depth as a separate variable.

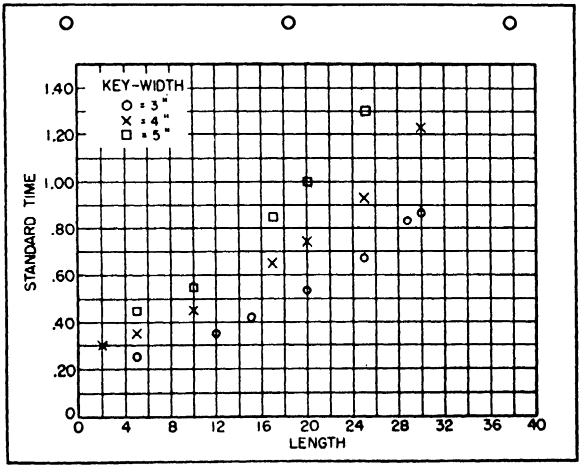
FIG. 16.

It is related to circumference by a constant 3.1416. Beside saving the time necessary to convert diameter to circumference, you make a bigger saving when you avoid this same conversion from drawing dimensions in standard setting.

Still, this "easier way" is the one to use. That is because there



(*a*) Not correct.



(*b*) Correct.

FIG. 17. Plot suspected differences in distinguishing symbols instead of seeking an over-simplified solution.

is no error brought in by short cutting in the analysis. And so, easier and faster ways are recommended. That is the essence of our whole theme. But be careful. Be sure to distinguish between short cuts in mechanics and short circuits in analytics. Repeating for emphasis what has been stated previously, we should plan for a complex solution. If it turns out to be simple, that's fine. But we should plan to save the backtracking—rework. So another rule might be

2. *Expect a family of curves instead of a single curve that might average a compound variable.*

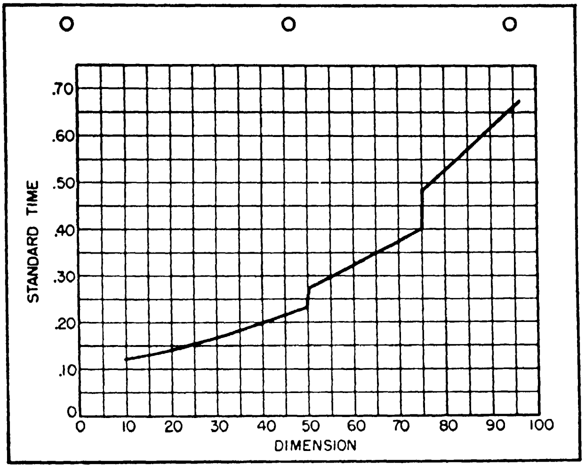
PER CENT RELATIONS

You might say, "Why not plot each of these curves on a separate sheet?" The question is a good one, if confusion results because there are so many curves in a set. But isolating the curves has a major disadvantage.

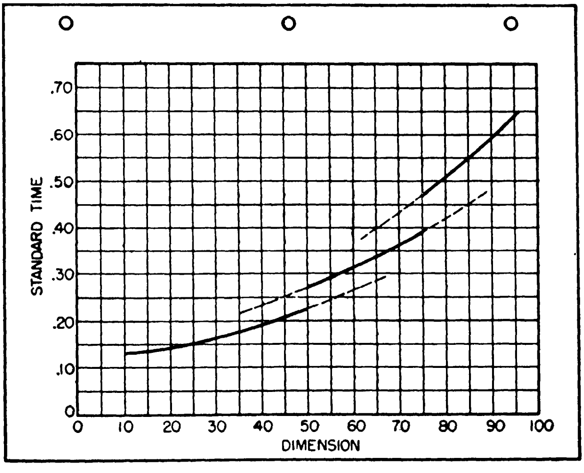
Each of the curves in a family is related to the others. Each should bear a percentage relation to any one of the others. This is an analytical phase that makes grouping more desirable than separating. All the curves of a family should have the same general trend. One curve of a family should not cross any other in that same family. Some may take exception to this statement because their experiences include contradictions. But a study of such conditions ought to bring out one of two reasons. Either there are differences in method or there are some errors in the standards.

Ordinarily, variation in method should start a different curve. The change introduces a different work content into the element standard, as previously mentioned. To connect the curve of one method with that of another would require a step. This is illustrated in Fig. 18. The example in Fig. 18*a* marked Not Correct shows an illogical connecting of three curves into one abruptly changing but continuing line. This method of drawing is not logical. Actually there are three distinct curves. The error is obvious if we extend the curves to overlap. The dotted lines in Fig. 18*b* show what would be revealed by timestudy if the three methods were used beyond the ranges assumed in the illustration.

Another variation may occur when curves show a tendency to cross. This can happen because of differences in methods less obvious than those just discussed. For example, suppose the studies were taken in a small department. Suppose also that one man did all the jobs at one end of the range. His way of performing the element being analyzed could be enough different to throw off the curve. But they are so nearly like the rest, that when one



(*a*) Not correct.



(*b*) Curves extended.

FIG. 18. The curves in this illustration have a spread of 20 per cent between them. That is the relation of one to the other but each is a portion of an individual curve. Each is not a part of one curve.

line is drawn to include them the pattern is upset. The curve takes a bend to the east that doesn't look right. It isn't.

"What to do?" you ask. And the answer is to draw the curve where it should be. That is the purpose of this discussion about percentage relationship. The point is this. People differ. They have different skills. They were trained or they learned by trial and error how to do the work. Even if all men working on a specific type of operation had been trained to use identical methods, still there would be noticeable differences after a few months of producing on their own. All of this refers to small differences that cannot be separated with the watch.

"What about micro-analysis?" is your obvious thought. "Maybe we should use motion pictures," is another. But remember, here we are using timestudy. Timestudy will be the method discussed for two reasons. Primarily, we are concerned in this book with ways to get economical measurement and incentives on work now largely overlooked. I refer specifically to jobbing, tailor-made products, maintenance, clerical, and the like. Such small quantity operations are not tuned up, are not standardized, and usually, are not measured. When these conditions continue in plants practicing the exact type of analysis, we must assume that exactness is too expensive for non-repetitive work. That means we have to use economical methods of work measurement or abandon the attempt to measure.

Now if we insist upon getting all work measured, then we must look to the methods. That is our objective in this book. With that in mind, let's look at the second reason. This one has to do with exactness too, but from the opposite approach. The question is, "Should we attempt to measure exactly all the tiny variations brought into the operations by the people doing them?" We know that they differ. Also, we know that they would get away from exactly following a method even if all were trained to use only one. This is repeating some of the fundamental principles discussed in Chap. 5. But here, we are trying to measure in numbers what is set forth in words in a job description. We are trying to set fair standards for the normal qualified operators. To do so, we must "draw the line where it should be."

The curve is a series of standards expressing in numbers only one set of conditions. Those conditions, not of work but of method, represent one skill or ability. That should be the normal called for in the job description.

Going from the specific of one curve to the general family, we apply the same reasoning. All the curves must represent the same normal skill. Therefore, they should bear percentage relationships to each other. The differences between them should be assignable to only the dimensional causes we are measuring.

3. *Curves of a family should bear percentage relationships to each other.*

STUDY THE RANGE

In the analysis just described, you have a picture of how the curves should be arranged up and down. Now we should look at them the other way. "How far across the page should they extend?" Studies must be taken over the entire range of the variables. Our purpose is to find out how standard times should change to compensate for differences in dimensional conditions. Of course, the extent of any range will differ from one plant to another. It may vary within the plant. It is in this connection that we want to outline the next rule of analysis.

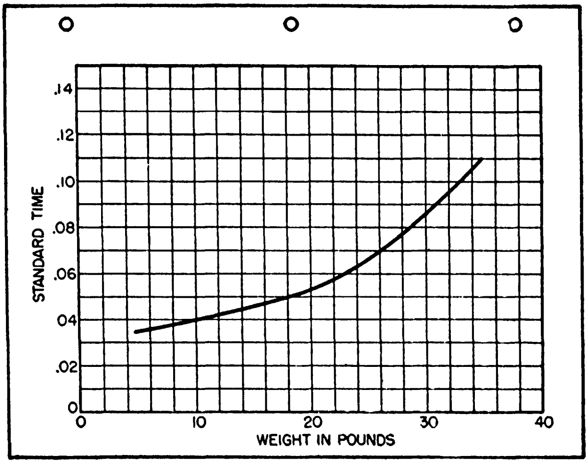
Plants are expanded departments. Back in the beginning, a few men made the product in a little shed somewhere. As the business grew beyond the abilities of one man to supervise, separate departments were set up. Often, the subdividing cut up the ranges of variables into several sections. To take our simplest example, maybe the Piece Handling now occurs as follows:

Department	*A*	*B*	*C*
Piece weight, pounds	5 to 35	20 to 50	40 to 80

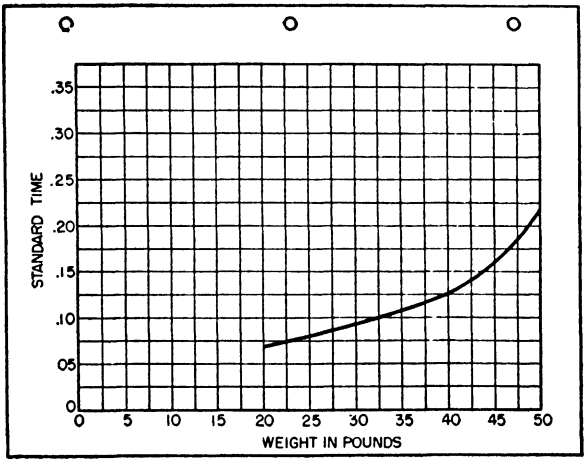
Naturally, you would take timestudies over this entire range if all sizes were in one department. You would plot all handling element standards on one curve sheet. Probably, you would draw one continuous curve to represent the standards for *Pick Up Piece.*

But usually, when timestudies are started in the plant, we overlook this important detail. We take our studies and work up data for Department *A*. Then maybe some other men are assigned to

Department *B*. To make the point, let's assume the worst condition, namely, that still another group does the study of Department *C*.



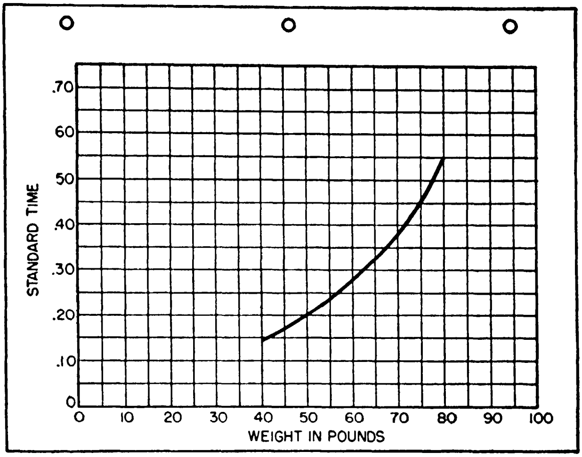
(*a*) Department *A*. Piece handling curve.



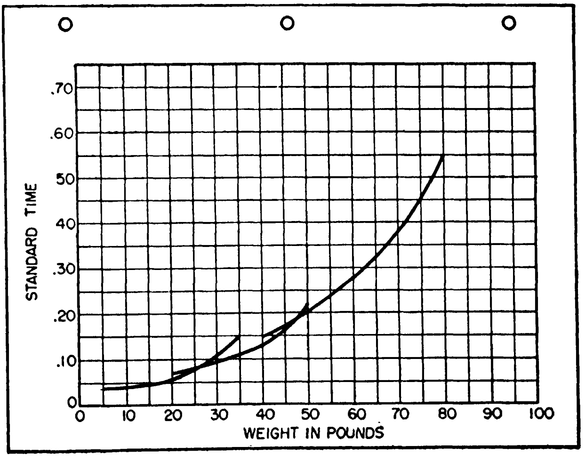
(*b*) Department *B*. Piece handling curve.
FIG. 19.

Already, you are way ahead of me. The three final Pick Up Piece curves would probably not form one continuous curve when superimposed. They might look like Fig. 19. But we know that the breaks in the summary curve (Fig. 19*d*), exaggerated to illustrate, should not exist. The curve should be smooth. That means all the element standards for Pick Up Piece should be plotted on one curve.

You counter with, "But we set up the standards in Department



(*c*) Department C Piece handling curve.



(*d*) Summary curve. The overlaps in the curves result when the three curves in this example are brought together. Each curve looks all right by itself. But the exaggeration shown here can happen when parts of a range are studied separately.

FIG. 19. (*Continued*)

A way back in June last year. Joe's group started in Department *B* seven months later. Shucks, Bill didn't start his studies in Department *C* until April." This can and does happen. It is more apt to be the rule than the exception. But study again the *Summary* curve. You know that it is wrong. Yet it may come out that way because the ends of a curve are extremes. The end sizes occur only once in a while. Because of this fact, we get fewer studies than we should of the least and the greatest sizes. We have lots of pressure on us to get the standards set. But we don't exert the same amount of pressure to bring the extreme sizes into production more often so we can get more studies.

The point I am trying to make here is that we must get consistency throughout the range. To attain this result, we must look beyond the immediate assignment for the studies we need. We will have to study all the range at one time or another. I do not want to get into planning here. That is the subject of our next chapter. Nevertheless, we can't overlook the necessity for taking studies over the entire range. These may be limited to sampling because of pressure to cover some department. And I can go along with this, because I do not believe in waiting until standards can be set for everything. That holds up coverage.

Your objective is to get standards that are consistent over the entire range. You may not succeed if portions are set up independently. At the same time, you have to solve each installation according to circumstances, and it is not good practice to hold up application until you have everything. That leaves the alternative of taking studies to check the variables outside the immediate range. This suggestion is one practical way to do your job and still follow the necessary fundamental.

4. *Study the variables over their ranges before establishing standards on any portion of their ranges.*

DO NOT EXTEND THE RANGE

Right along with the subject of range goes another important factor in curve making. It is a detail. Yet failure to observe it can lead to errors in application. It is brought up here because the error made is in analysis. You might contradict by saying that it is a detail of curve drawing.

The fact is this. Assume that you have a group of plotted points. You are all set to draw the curve. You may not do what some have done, but regardless, it is a mistake to extend a curve beyond the limits studied. It is so easy to extend the line a little bit. Perhaps this is done without a second thought. But here's what happens. In the first place, most timestudy curves are concave upwards. Consequently, an extension on either end is likely to produce tight standards. Second, it is a mistake to go beyond the data. You have no right to do that. That is guessing. And if you can guess an extra 10 per cent beyond your studies, your successor may go you one better. Before many years have passed, you wouldn't recognize your original curve.

Back in 1919 at Westinghouse, my boss insisted that we draw big road blocks in India ink at both ends of a curve. He figured that it would be obvious if any extending were done. That is one approach. I do not recommend that one. It savors a little of the childish. But the idea behind the symbol is thoroughly sound. So let's make it a rule.

5. *Do not extend the curve beyond the limits of the timestudy data.*

ANALYZING THE FAMILY

What we want to develop here will seem to contradict our Rule 5. But you will recall the previous discussion about percentage relationships in the family of curves. Under these conditions we can extend curves. And this is the reason. Suppose we start with a simple analogy. It is not a very good one because timestudy curves are usually curves. But you know that it is correct to draw or extend one line that is 30 degrees from another. The 30 degrees is taken here as being similar to the percentage relationship in Rule 3. Putting Rule 3 and 5 together gives us another analytical tool. It must be used with caution. Like anything else, it can be overdone. Remember, I said *analytical* tool. So use your head.

The idea is helpful in dealing with the family of curves. Frequently, each curve has a different range. Some of the differences result from actual limitations in sizes. Also—and this is the principle—we need not study all the sizes. We can follow the rule used when there is only one curve. We say that we need a representative number of studies all along the range. Then why not understand that often a family of curves is only a vertical expansion of one curve introduced by a modifying variable?

It follows that you can tackle many such problems more effectively by using some planning:

1. Concentrate your studies on the sizes that make up the major part of the range on one curve factor.
2. Study the curve to get it most accurately placed.
3. Spot the other curves with studies representative of their weighted activity.
4. Take enough studies, regardless of activity, to obtain a representative trend line.
5. Draw in the remaining curves in percentage relationship when this rule applies.

The procedure outlined permits you to extend all curves to the limits studied on any one. Remember however, this seeming contradiction must be used with lots of good common sense.

HOW MANY CURVES?

Along with the other analytical problems, there is another affecting the family of curves. It is the answer to the question "How many curves are there in a family?" This phase of analysis will be discussed more fully in connection with chart making. Here it is necessary to show how to apply the principle in curve analysis.

Earlier in this chapter, you saw two curves in Fig. 16. You read the statement that in this example there was a spread of 35 per cent between the low and high in plotted points. Obviously, the per cent at the top of the range is different from the per cent at the low end. That is a detail. You can take care of it after you grasp the idea explained here.

In the plotting in Fig. 16*b* marked Correct, the difference between curves was only 10 per cent. That would be too much, in my opinion, in highly repetitive operations. But, again as I apply the rule, it is *practically* accurate for jobbing operations. The point is that accuracy costs money. The fact applies in standard setting just the same as it does in milling, drilling, or most other shop operations. For that reason, we have to consider cost. Our purpose in this book is to find economical ways to measure work that many people say "will cost too much." At the same time, I am not granting a license to commit wholesale errors.

Maybe you would understand all this in terms of tolerances or limits as we use them in the shop. Repetitive and interchangeable parts are made to close tolerances. Tailor-made products usually have bigger tolerances. Part of the difference results directly from tooling or the lack of it. We do not make tools for the small quantity orders. We can't afford them. Consequently, we cannot get the accuracy. That is different, I know. We can get more accuracy in timestudy if we do spend the money. But that is a part of the consideration. The question is how to measure economically the many operations that have not yet been put on incentive.

One of the details of cost is involved in this question, "How many curves in a family?" This and like questions have been raised innumerable times. I have had to find a rule to go by. It is one that gives weight to the factors of both fairness and cost. Inaccuracies in work standards are unfair, either to the employee or to the company, as we erroneously express it. We should say, "unfair to the consumer."

Naturally, if we deliberately create some inaccuracies, we must know what we are doing. To get down to cases, let's solve a specific problem. Take Fig. 20 as an example. In it, you have a common, everyday complex variable. The Area ranges from 100 to 450 square inches. The Depth varies from 2½ to 6 inches. The plottings show a spread of 30 per cent, approximately.

"How many curves should we draw?" Your answer would be, "More than one, anyway," if you agree with me that 15 per cent plus and minus is too big an error. Then you might start in as most men do by adopting steps in Depth, say 1-inch increments. That approach would give you four or five curves. You would say that you had the right number because you made the decision to use 1-inch steps. One of your fellow timestudy men might have chosen ½-inch steps. He would have come up with eight curves. This method of approach produces inconsistencies, as you can see. The reason is that these adopted solutions do not have reasons behind them. They may even be expensive to adopt because you argue for 1-inch spacing and your timestudy man wants to use ½-inch intervals.

Both are wrong for one reason. Both result in uniform dimensional scales. I maintain that the dimensional approach is wrong to start with. To have consistency, we must start with a uniform per cent interval in the standard times. The approach results in a varying increment in dimensions. What the percentage should be is something you will have to decide. When you do decide, you will have established a consistency. All like problems can then be solved in the same way.

To give you something to chew on, let me put down the tolerance ranges that I recommend:

1. For repetitive operations, 5 per cent
2. For non-repetitive work, 10 per cent
3. For some types of miscellaneous maintenance jobs, 15 and even 20 per cent

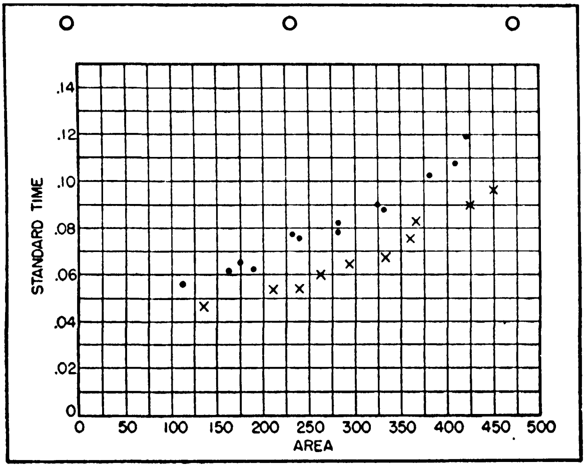


Fig. 20. The spread in these curves is about 30 per cent. Only the top and bottom points of the spread are shown to make this an example requiring further analysis.

Those are generalities. But they grow out of long experience in measuring the "impossible" types of operations. More will be written on this phase in the sections where some of the working charts are developed. Hence we will conclude with Rule 6:

6. *Use a uniform per cent spacing in setting up the number of curves in a family.*

WHAT SHAPE OF CURVE?

None of the several factors of curve analysis we have discussed thus far helps us in shaping the curve. That most curves have a concave upward shape has been mentioned. "How do you know?" is the question we want to answer now. Perhaps the easiest way to explain is by example. Take Piece Handling, to illustrate. The curve heads skyward for the heavy weights. The reason is obvious, if you stop to think about it. Suppose the maximum you could lift was 150 pounds. If that is the absolute maximum, then you could not lift 151 pounds even if you were allowed all day to do it.

As you approach the maximum, each added pound takes more time than the pound just before it. That extra amount is what causes the bend upward. It means that we must allow more for the eighty-first pound than we do for the thirty-first pound. The same general effect is produced by added lengths, areas, and volumes. The larger ones tax the reach, strength, and other capacities of the individual. Because of this approach to capacity as dimensions increase, we get the concave upward curve in timestudy.

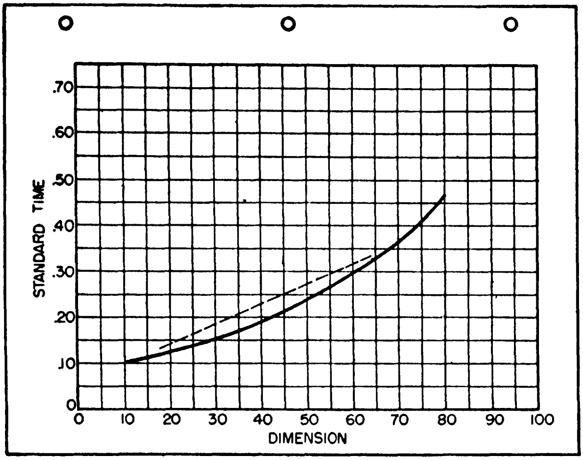
You may object by saying, "But I have seen a lot of straight-line curves in timestudy." That is true. Some could have been straight and correctly so. There are plenty of straight-line curves that are mathematically straight lines. Machine-time curves are common examples.

Contrariwise, we see many curve lines that are drawn straight because it is the easy thing to do. But wait. Some of these straight lines are correct within limits. Take a simple example. You have seen or heard about the Western prairies. They look as flat as a tabletop. But we know they curve somewhat in relation to the earth's surface. Obviously then we must think on terms of degree. In reality, we are back again to the per cent accuracy discussed previously.

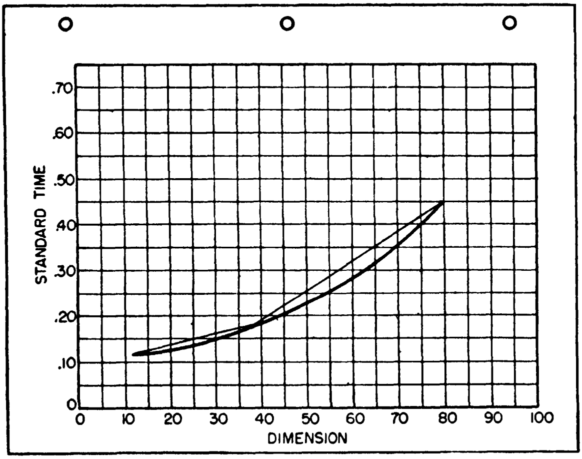
CONTROL THE ERROR

Look at the curves in Fig. 21. Curve (*a*) represents a possible range of a variable. In this instance, a single straight line would be greatly in error if drawn in place of the curve. The maximum error in the illustration is about 24 per cent. However, we can break up the curve into a series of straight lines. Curve (*b*) shows the approximations. Curve (*b*) is only an example set up to indicate how the full range may be sectionalized under actual shop conditions. When this happens, a straight line can be used while holding the error within prescribed tolerances. See Fig. 22 for the method to use.

Let's move on to the next step. In Curve (*c*) of Fig. 21, we show



(*a*) Not correct—maximum error about 24 per cent.

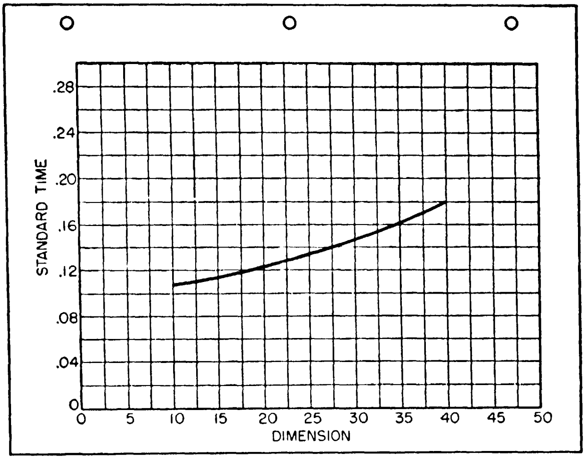


(*b*) Straight lines approximate a curve within reasonable limits of error. See Fig. 22 for the method to use.

FIG. 21. Examples showing the relations between straight and curved lines.

how the curve would look if our range were only from 10 to 40 pounds. This curve has been drawn in accordance with Rule 3 in the previous chapter. There we specified that the scales used should be the largest we could use practically. As a result, the section that is noticeably curved in Curve (*b*), seems almost straight in Curve (*c*). It would be even straighter if the section of the range were shorter. So we come down to the question, "How straight is a curve?" And our answer must depend upon per cent of accuracy. We can use a straight line when the error is within limits.

Two important cautions must be stated before we go on. First, remember our Rule 5 that prohibits the extension of curves beyond the range of timestudy observations. Applied here, the result might be that, at some future time, a straight-line substitute would have to be changed back to a curve. This would be necessary when the extended part of the data showed the straight line to be more in error than prescribed by limits.



(*c*) Enlargement of lower section of Curve (*b*) showing a line that appears almost straight.

FIG. 21. (*Continued*)

THE CURVE CONSTANT

The second caution is also another part of our analytical efforts. The caution is to watch out for the constant element that usually exists with every curve. The constant is the amount of standard time allowed at 0 Dimension. This constant may show up only when the curve is projected to the time axis. But there is some constant in almost every timestudy curve. As to the caution, you can see in Fig. 22 what is meant. The dotted curve illustrates the supposed true curve. It would have a constant of about .07 minute. On the other hand, the straight line projected would reveal the constant as a minus amount. This is contrary to the analytical point we are trying to make in this section. It should be self-evident that any extension in the low end of the range would require a change back to the curve. Only a slight change would bring a per cent of error greater than any reasonable tolerance. To reduce this to arithmetic, the spread between the true curve and the straight-line substitute is about 10 per cent at the lowest reading of about 17 pounds. At an extension to about 13 pounds, the curve would read .09 minute and the straight line .06 minute, approximately. Now the spread is 33 per cent, calculated from .09 minute.

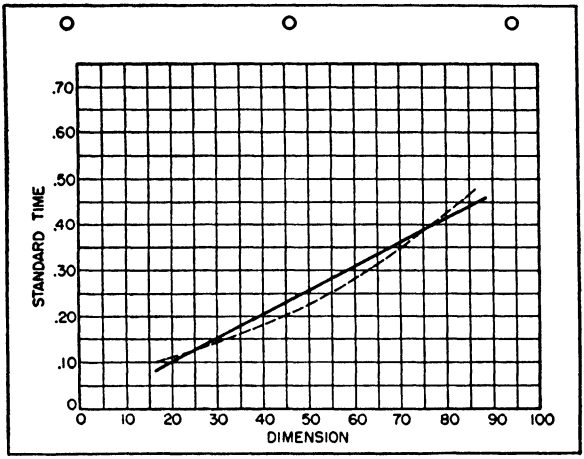


FIG. 22. A straight line used instead of a curve with small error.

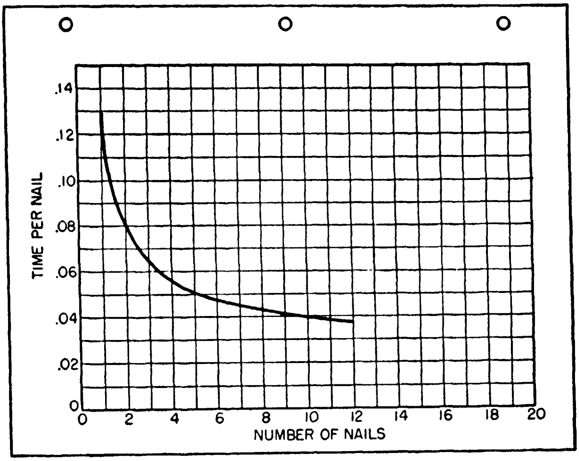
Analytically, the constant is extremely important in the lower ranges. It can have a large percentage influence on the standards in the small sizes. The effect is so important that I recommend an enlargement of the lower part of a large range. This need be done only when the small sizes approach 0 Dimension. You might make it a rule to blow up the lower 10 per cent when the curve approaches 0.

Summarizing, we might set down a rule on the shape of the curve as

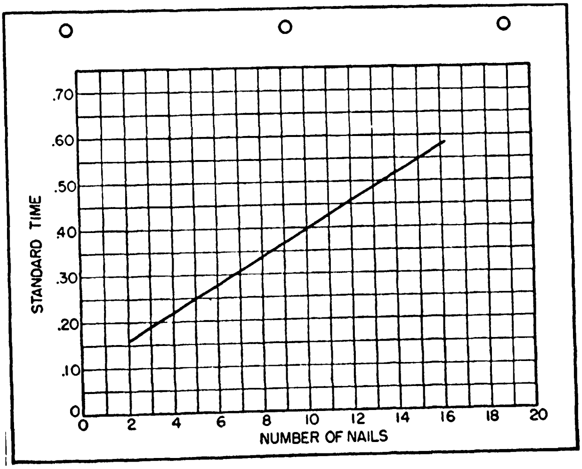
7. *Expect the variables to take the concave upward shape with a definite constant time indicated for 0 Dimension.*

THE "PER EACH" ERROR

Next comes a detail in data preparation that misleads some time-study men. Maybe you have tripped over it. The difficulty



(*a*) A reciprocal curve results from prorating a Constant.



(*b*) A better and easier method is to plot against Number.

FIG. 23. Curves showing the correct way to analyze Standard Time elements that seemingly should have a constant per unit value.

comes about largely because of the constant previously discussed. It shows up when you seek a common denominator to a variable, usually of number. So you divide your element standards by the quantity to get a "per each" answer. This is the mistake. You cannot get a correct analysis then, because the constant has been prorated. Only after you have made the most careful kind of timestudy and excluded all constant time can you get away with this slide-rule leveling process.

The mistake is one of over-simplification. We attempt to make a constant "per value" out of a variable. Suppose, to illustrate, that we had computed some standards per nail for coremaking or molding.

Study Number	1	2	3	4	5	6	7
Set one nail.. ...	.080	.047	.055	.040	.050	.043	.038

Several of these answers have come out reasonably close together but that is only accidental. We still have a variable. If we knew enough to plot our inconsistent answers, the result would look like Fig. 23*a*. But we might not analyze correctly. The easy thing to do would be to pick a value, or even worse, take an average.

My recommendation is to avoid the clerical effort of dividing and the error of trying to arrive at a constant. Instead, plot your data against *Number*. (See Fig. 23*b*.) This is better practice, in my opinion, even if the constant does wash out because quantity is large relatively. This approach is better engineering and the final analysis is right, not wrong.

8. *Plot curves for elements that appear to have per unit values using Number as the dimensional factor.*

With this, we should move on to the next chapter. The important analytical points have been outlined here. But there is another important function the curve can perform. To my way of thinking, it is very useful as a production control device. How to get the most from our timestudy effort by planning will be our next subject.

CHAPTER 10

CURVES AS PLANNING CONTROLS

"How many points are necessary to determine a straight line?" You answer, "Two." "How many for a circle?" You say "Three." "How many points are necessary to establish a curve in standard time data?" Your reply may be, "That depends." It does. The number should be related to the measurements we must have. And yet, I find that usually we waste time on timestudies at points in a range even when our data is poorly supported by insufficient studies at other points.

The paradox is the same one we see in the shop every day. We go out to take a study of an assembly. We find that the assemblies cannot be completed because all the pieces are not there. We have too many of some and not enough of other parts. Planning has fallen down. Yet in timestudy, since we are not controlled by physical limitations such as the absence of nuts, bolts, and washers, we may "complete" our data because the boss says to start the installation next Monday. It isn't any more complete than the assembly. But—we may not know it. At the same time, we have too many studies of certain operations. The reason is that we did not plan any better than Production Control scheduled the parts for assembly, if as well.

THE VARIABLES CONTROL

Look at it this way. If you worked like a "rate setter" from individual studies, you would handle every element as if it were a constant. If, later, you decided to build data, you would not need very many studies if all the elements actually were constants. But as soon as variables must be considered, the data solution really becomes the solution of the variables. The constants are relatively easy to determine. Actually, you get more studies of them than you need. Obviously then, we make our efforts productive according to how well we control the studies of the variables.

Returning to the opening question about a straight line, we remember that only two points are required. However, that has only the slightest bearing on our approach because variable element lines are curved, as a rule. But it serves as a ridiculous extreme to emphasize the point. Let's put it another way. Suppose you were plotting the solution to a formula. You would spot points at intervals. You would plot more points where the curve changed rapidly. You would skip more space where the curve was relatively flat. The points might be about an inch apart. You would need only a few points because you had the shape of the curve expressed in a formula. In contrast, we are seeking the timestudy curve. We do not know what its shape is. But is that any reason for getting fifteen or twenty times as many points as are required?

Theoretically, we do not need any more than a representative number of points spread out over the entire range. Surely that would be all that were needed if we could rely absolutely on each one to be correct as with a known equation. Suppose we double that number to satisfy ourselves. Then add in the extras we get "fer nuthin." The extras come from studies taken to get readings on some other variable we need. All these together are not nearly as many points as we usually have. Why?

CARELESS TIMESTUDY

We do a lot of indirect labor for two reasons. The first I will try to explain by using an incident. This happened in a training group. The trainees had each performed an operation designed to provide timestudy practice for data. The observations made were for a range of distances. At the conclusion, the instructor said, "Now compute your element standards. Plot them. Then draw in your curve."

After considerable time, one of the trainees said, "I think we need more studies." After some discussion, it was decided to repeat the sequence. That gave each man double the number of points. When these were plotted, the instructor asked, "Did the added observations help you?" The answer in chorus was, "No!"

Of course, these men were trainees. Their studies were rather poor. Yet, at least one man thought he could improve upon the results of his poor timestudies by taking more of them. Whether you call it indecision or attempting to average errors, the result is the same. We take too many studies because they are not sufficiently correct. We try to bolster the weakness of the studies with a mass of observations. That wastes timestudy time. We should remove the causes, as described earlier in Chap. 9.

DUPLICATION

The extra points resulting from poor timestudy are irrelevant to our theme of planning. But they all look alike to the unpracticed eye. I had to get them separated from our thinking. Now for the extra studies caused by failure to plan. They just happen. Often they are "leaf raking," if you want to be blunt. The timestudy man runs out of work and asks, "What do you want me to do next?" You know, the way a person does in the office or shop. He is given work to do to keep him busy. What he does may accomplish no more than just that.

This sort of duplication and other studies taken intentionally can be saved by planning. Here is where curves for variables can be made to perform a valuable by-product service. To do it, however, they must be started with the first studies.

PLOTTING AND PLANNING

The anticipated curves should be laid out at the start of the project. They should provide for the ranges of the variables. The extremes of the range should be determined, perhaps, even before studies are started. In similar research projects the experts say, "Define the problem." In defining yours, do not restrict yourself to studying only part of the range. Note again the fundamental on this phase of analysis described in Chap. 9. Set up to check, at least, the full ranges of the variables.

With curve sheets set up, the first few points obtained can be plotted. Ordinarily, these will fall around the "average job." Right away, the production control should start. It is this easy-to-find study of the regular work that brings about most of the duplication. To save time, you want to stop further study of these "average jobs" as soon as you have a representative number. Place the emphasis on those studies you do not have.

See what you can do to get the extremes produced so that you can get studies of these sizes. Almost always these extremes hold up the concluding of your data. They are the jobs most unlikely to occur. If they come through once in 6 months, just to make an example, then the probabilities of timestudy might be about as follows:

Type of Job	*Probable Studies*
Extremes	Studies every 6 months
Next to extremes	Studies every 3 months
In between	Studies every month
Near average	Studies every week
Regular	Studies every day

You would not want to be restricted to only one study of either extreme. You would try to get several. Suppose you were unable to get more than three studies of each extreme. Then to emphasize my point, and refer again to the straight-line question, let me ask, "Do you need more than three of those between the extremes?" Before you say, "Yes," let me ask, "Would you set a standard for an operation from one study?"

Please do not be misled. Far from trying to skimp on timestudy, I am insistent upon building sound data. I personally refuse to set standards from single studies. I get three or more before reaching a conclusion. But the point here is that some timestudy men will draw in a curve with a study or two of the extremes. Yet they will have dozens around the average. Many studies of the regular work are unnecessary waste. The time might better have been spent studying some type of work not yet on incentive. That is where you can improve timestudy efficiency by planning. You can control the number of studies. You should limit them to the jobs you need in order to get representative curves for the variables.

UP-TO-DATE PLOTTING

Beside controlling production, the immediate plotting of studies gives two other values. We discussed one in Chap. 9—the detection of errors. There we likened curve plotting to a go–no-go gauge. That measurement of timestudy results is important in saving wasted time. From my point of view, if the plotted point is wrong, the whole study is wasted. You disagree. You say, "All the other element standards add to the data." Then I counter, "Yes, but come back to our exaggerated straight-line question again." You would not have needed to take another study of the variable at fault if it had plotted correctly. So in the restudy, you get an added set of readings on all the other elements you would not have taken. There is the waste.

Just the same, the curve plotting is extremely important to minimize the number of faulty studies. But the plottings must be right up to the minute. Otherwise, the number of faulty studies can multiply. You know what I mean. You have it in Quality Control. You sample on schedule to see that quality is kept in control.

CHECKING DIMENSION FACTORS

The other value in up-to-date plotting is also a "quality control" item. We touched on this in Chap. 9. There we used two curves to illustrate. One was plotted against Area. The other used Volume as a dimensional factor. Those are comparatively simple examples of possible errors in analysis. Even so, you want to find out as soon as you can if you are off on the wrong foot. You want to verify the correctness of your analysis. Therefore, you need to plot the study results to see that they do line up.

In job shops, this is most important. The work is often finished and gone shortly after your studies are made. And if you have wrongly planned to use certain dimensions, your study may be worthless. You may be unable to get other dimensions you need. I remember a case. The timestudy men asked the boss, "What next?" He was busy solving a problem. So he gave them some quick instructions and assigned them to a new type of work. He continued to be busy. Several weeks went by. Studies piled up until there were about fifty of them. Then when the boss did take a look, you know the result. He had guessed wrong on controlling dimensions. The necessary ones were not obtainable. The men had been wasting their time, as things turned out, because new studies had to be made.

That result may seem farfetched to you if you are accustomed to repetition work. If so, it is because you can almost always get, from repeating orders, the information you failed to record when the study was taken. But job shops are different. They are way back in product history where repetitive operations were started. And in nearly every plant, this same condition still exists with most setup operations, maintenance work, toolmaking, and the like. Remember that timestudy itself brings about considerable development of engineering detailing.

So don't get caught short. Don't let studies accumulate. Plan to control the results. Check the analysis by plotting the variable standards. Make sure that the dimensional factors you have chosen are the right ones. Follow up day by day, as you must do with any planning or quality control that works.

MAKING HAY

The suggestions given here are part of my effort to help you get incentive coverage. They are not academic. They have grown out of experiences and observations of mistakes made. Why not learn the easy way, for a change?

All the material in this book is pointed in the same direction. The intent is to help improve timestudy methods. The main object is to get total coverage. To do so requires methods we can afford. My over-all effort is not one cure-all system. It is made up of a lot of little items like Ben Franklin's, "Take care of the pence, and the pounds will take care of themselves." With this approach to savings in mind, we will go on to the mechanics of data presentation. The latter chapters are geared more in line with "how to make the most of what you have." Those we are concluding here are directed toward saving the wasted portions of the necessary studies. Actually, then, we have two sources for improvement. As "Chief" C. D. Dyer once said, "'There are two times to make a profit—before you take the order" (right pricing) "and after you get it" (cost reduction and cost control).

Keep before you the theme of cost reduction. As you proceed, critically analyze each method of setting up data. Each has certain advantages. Under some conditions, these outweigh the disadvantages. Remember, we try to use the most economical method of the several available when we produce articles for sale or for in-plant use. The same principle should be applied in our standard data preparation. We must strive to get the cheapest over-all cost per standard applied while retaining its correctness. Only as we approach that goal can we achieve total coverage by incentives at a cost we can afford.

CHAPTER 11

EQUATIONS IN TIMESTUDY

Sometimes, in charting standard data, we need to use equations. Occasionally the equation is the best way to express the relationship between standard time and its controlling dimension. It may be best because it is convenient, simple, and, once in a while, the only applicable method. But don't stop here. What follows will be an explanation of only those equations we need to know about. Certain equations may be written directly to summarize constants in the data. As a rule, however, our solutions involve some variables. These factors must be derived from one or more curves when an equation is the form desired. Sub-dividing the topic of equations even further, we know that many straight-line curves are used in standard data. This is so for two reasons. One is that a straight line is often drawn for a section of a curve that has only a slight curvature. The other is that sometimes we are too inclined to simplify by forcing a straight line in place of a curve. As long as the error resulting from either practice is not outside the established limits, there is no objection at this stage. But be careful to check again if there is any extension of the straight line.

THE STRAIGHT LINE

The straight line is the simplest form of curve. It has an equation that is easy to determine. The line is like a road going uphill. We say the road has a certain "grade." A 5 per cent grade means that there is a rise of 5 feet in 100 feet. This grade in an equation is called the *slope*. The slope is the rate of change. This is uniform with a straight line. In operations like painting, it would be expressed as so much time per square foot. In shoveling, it could mean so much time per 100 cubic inches. Figure 24 is an attempt to show how a curve may go up one unit of Standard Time for each unit of Dimension. This diagram is similar to stairs that have a rise equal to the tread.

With a timestudy straight-line curve, we see it in the same way.

But the slope may be anything. That is unimportant because we compute what it is. Take Fig. 25 as an example that is a little more complicated. If you look closely, you will see that the Time increase is .06 Minute for each 4 units of Dimension. That means the slope is .06/4 or .015 Minute per Foot. To express this as an

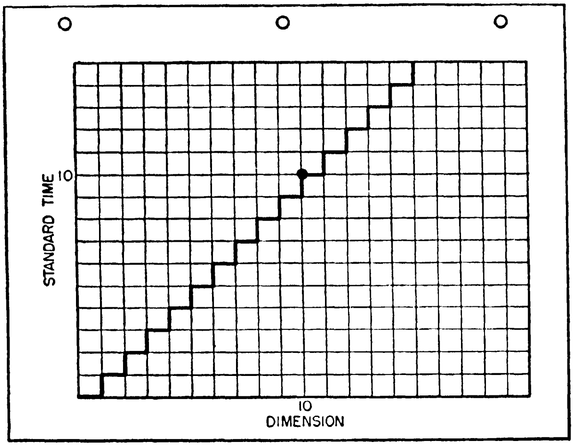


Fig 24. The Slope of a timestudy straight-line curve is usually equal to a unit time rise for each unit of dimension, like stairs.

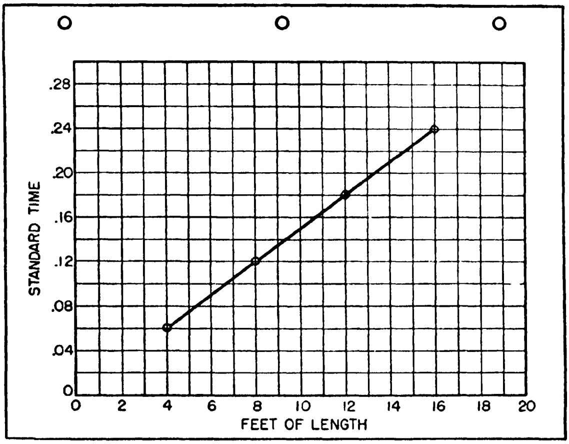


Fig. 25. The Slope is equal to .06 minute rise divided by 4 feet of dimension, or .015 minute per foot.

equation, we write it

$$\text{Standard} = .015\ \text{Min/Ft} \times \text{Ft}$$

or

$$\text{Standard} = .015\ \text{Ft}$$

The everyday problems do not line up quite so conveniently. Next, let's take a curve that is a bit more like one we may have tomorrow. Figure 26 is an illustration. We will find the slope in this problem as we should determine it with any straight line.

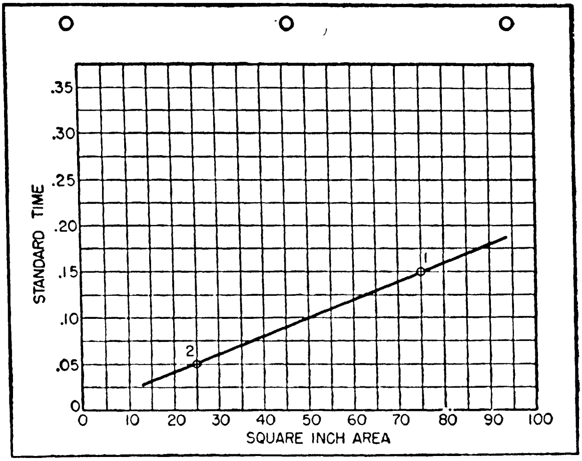


FIG. 26. Read the straight line at two points as close to the extremes as they can be read accurately.

Step 1. Read the curve at the point of largest dimension you can determine accurately. This is .15 Minute for 75 Square Inches. We could get out much further if the curve were drawn on regular cross-section paper.

Step 2. Read the curve at the lowest point you can accurately. Here we have .05 Minute for 25 Square Inches.

Step 3. Set these down in an orderly arrangement like this:

Point	Square Inches	Standard Time
1	75	.15
2	25	.05

Step 4. Subtracting: 50 .10

Step 5. Dividing: $\frac{.10 \text{ Min}}{50 \text{ Sq In.}} = .002 \text{ Min/Sq In.}$

Step 6. Prove your solution by taking an example different from either one used in your computation. One in between is 50 Square Inches. At this point our curve should read .002 Minute × 50, or .10 Minute. It does, so the slope of .002 per Square Inch is correct. Our equation, then, is

$$\text{Standard} = .002 \times \text{Sq In.}$$

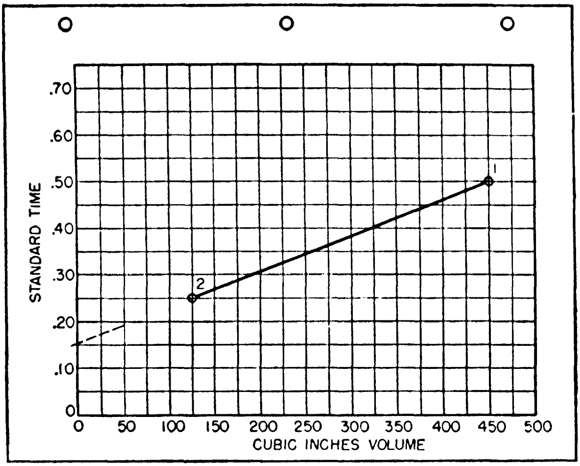


FIG. 27. Timestudy curves usually have a Constant Time at 0. This must be included in an equation for the curve. It may be computed or read off by extending the line.

CONSTANT AT ZERO

Did you notice that the examples used thus far were of curves that would pass through 0-0? These were arranged that way on purpose. But most curves, if extended to the 0 Dimension axis, have a constant Time Standard. This point was emphasized in leading up to Rule 7, Chap. 9. For this reason, we need to take the next step and consider the more usual type of straight-line curve.

There are two approaches. One is to visually extend the curve to read the constant (Fig. 27). The other is to calculate it. We will use the latter method as procedure and the graphical method as a check. Figuring the slope as before, we have

Point	Cubic Inches	Standard Time
1	450	.50
2	125	.25
Subtracting:	325	.25

Dividing: $$\frac{.25 \text{ Min}}{325 \text{ Cu In.}} = .000769 \text{ Min/Cu In.}$$

The slope in our equation is .000769 Minute per Cubic Inch. However, the total standard has to be more. It contains the added amount of the Constant. So our equation will have to read something like

$$\text{Standard} = \text{Constant} + .000769 \text{ Min/Cu In.} \times \text{Cu In.}$$

At 450 Cubic Inches, the standard we used is .50 Minute. Therefore, if we put that in our equation, we can solve for the Constant.

$$.50 = \text{Constant} + .000769 \times 450$$

Multiplying, we have

$$.50 = \text{Constant} + .34605$$

Transposing, the result is

$$.50 - .346 = \text{Constant}$$

$$\text{Constant} = .154$$

Now we can set up the final equation as

$$\text{Standard} = .154 + .000769 \text{ Min/Cu In.} \times \text{Cu In.}$$

This checks closely with a reading made after extending the curve to 0 Cubic Inch. Our arithmetic works out correctly.

COMBINING EQUATIONS

When you have equations for several curves, you may want to combine them. This may be for use as a formula. I would prefer to go on to make up a table or chart. At this stage, it may be advantageous to add them together. To make an example, we might combine the curves in Figs. 26 and 27 with some other values. Suppose we had two element standards .06 and .05 that were Constants from our Comparison Sheet. Also, imagine we have another curve that has a Constant of .025 Minute and a slope of .012 Minute per Square Inch. Set down in form so we can see what we have, the starting figures would be

Source		*Min/Sq In*	*Min/Cu In*
(Comparison Sheet):	.0600		
(Comparison Sheet):	.0500		
Figure 26:		+ .002	
Figure 27:	.0154		+ .000769
A third equation:	.0250	+ .012	
Adding, we have Standard =	.1504	+ .014	+ .000769

This is a simple example, but it shows how to combine. Only one detail is important. Be sure to avoid trying to add "horses and apples." Add together only those terms that are alike. You will find that this step is easily made when you set down all like factors in column form as in the foregoing example. This illustrates one use we can make of equations in timestudy work.

INTERSECTING LINES

Another useful application of equations is in solving certain kinds of problems. One type found in timestudy is to find the intersection of two lines. Two illustrations arise in answering the questions

1. What is the quantity of pieces to be made when we should change from one method to another?
2. What is the economical cutting speed to balance labor costs with tool costs?

Of course, you can plot the figures and read off the answers. Probably, you would use that approach. While that is a slower method in the solution of Question 1, the quantity for changeover, it is also never-ending. A chart is the best solution to the recurring type of problem. Notwithstanding, you should know the equation method for solving an occasional problem.

The fundamental rule to remember is that

Two straight-line equations are equal to each other at the point where their lines cross.

Applying the rule to Question 1, "What quantity?" you can simply set down the two equations equal to each other. As a problem, we have

Lathe	Setup Minutes	Operations Minutes
Engine	20.0	4.0
Turret	50.0	1.9

The equations of these two straight lines would be

Engine lathe Standard Time = 20.0 min + (4.0 × Quantity) min
Turret lathe Standard Time = 50.0 min + (1.9 × Quantity) min

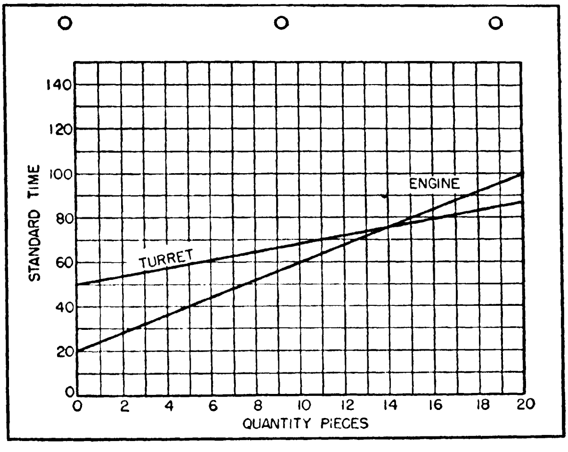


FIG. 28. The economical quantity where method should change is at the point of crossing of the two curves of total time.

The Quantity we want to determine is the economical number of pieces where we change method. It is the same Quantity in both equations. It is where the two lines cross each other. The total Standard Time for the lot produced either way would be identical at this point. For that reason, then, we can set these down equal to each other. With Q standing for the Quantity, we have

$$20.0 + 4.0Q = 50.0 + 1.9Q$$

Collecting like terms, we get

$$\begin{aligned} 4.0Q - 1.9Q &= 50.0 - 20.0 \\ 2.1Q &= 30 \\ Q &= 30/2.1 \\ Q &= 14.3 \text{ pieces} \end{aligned}$$

We purposely went through this solution of equations by mathematics to make a point. It should serve to demonstrate a method. It can be used many times in a variety of forms to solve timestudy problems. My personal opinion is that sometimes we can analyze even better by setting down the problem in simple algebra. With that, we can refer to Fig. 28 to see the example in graph form.

SHORT ELEMENT TIMES

Another use for equations is in the breakdown of timestudy for data. Two applications are commonly required. First, there is the necessity for sub-dividing watch readings too short to observe and to record. You may have run into this in fast punch-press operations.

For practice, let's work out a problem. We have a study on an operation made up of four elements. We can call them *a*, *b*, *c*, and *d*. Our data requirements make it necessary to get separate element standards for each one. My recommendation is to take observations in several ways on each study. Maybe you will time 10 cycles one way, 10 another, and so on. In any case, you should get over-all readings also. Then repeat all sets of readings in several ways. The purpose is to reduce the errors in your assumptions. You cannot have true equations. There are the variations caused by both the operator and you, the observer. You may be off ever so slightly in rating, watch reading, or method change inclusion. These are errors when you apply equations. The algebra you write down with an equal sign may not be an equation.

Let's take some watch readings to work out a sample problem.

Elements		*Minutes*	*Observations*
$a + b + c$	=	.045	(1)
$b + c + d$	=	.045	(2)
$c + d + a$	=	.035	(3)
$d + a + b$	=	.055	(4)
Total cycle	=	.06	(5)

Arranging the equations so we can add them, we get

$$\begin{array}{ccccccccl}
a & + & b & + & c & & & = .045 & (1)\\
 & & b & + & c & + & d & = .045 & (2)\\
a & & & + & c & + & d & = .035 & (3)\\
a & + & b & & & + & d & = .055 & (4)\\
\hline
3a & + & 3b & + & 3c & + & 3d & = .180 &
\end{array}$$

Dividing by 3, the result is

$$a + b + c + d = .060 \qquad (5)$$

This checks with our total cycle time. We must have the same total. That may seem silly for me to mention. In short, a learned man once sent me some actual cases to work out that had different totals. The check is necessary because all our starting observations include only three of the four elements.[1] One is omitted for ease in algebraic solution. Next, we solve for our unknowns.

$$\begin{array}{lrcll}
 & a + b + c + d & = & .060 & (5)\\
 & b + c + d & = & .045 & (2)\\
\cline{2-4}
\text{Subtracting:} & a \qquad\qquad & = & .015 &
\end{array}$$

$$\begin{array}{lrcll}
 & a + b + c + d & = & .060 & (5)\\
 & a \qquad + c + d & = & .035 & (3)\\
\cline{2-4}
\text{Subtracting:} & b \qquad\qquad & = & .025 &
\end{array}$$

$$\begin{array}{lrcll}
 & a + b + c + d & = & .060 & (5)\\
 & a + b \qquad + d & = & .055 & (4)\\
\cline{2-4}
\text{Subtracting:} & c \qquad & = & .005 &
\end{array}$$

$$\begin{array}{lrcll}
 & a + b + c + d & = & .060 & (5)\\
 & a + b + c \qquad & = & .045 & (1)\\
\cline{2-4}
\text{Subtracting:} & d & = & .015 &
\end{array}$$

DIVIDING OVERLAP

The second use of the equation method is in dividing the overlap found in some types of work. One case will serve to illustrate—filling, sanding filler, or brush painting of small castings. The observer could get only partial breakdowns because the painters would overlap the data divisions. These are the segregations of bosses, areas, and edges. The painter would not know what the observer wanted. It wouldn't make any difference if he did. He would be busy working on the castings. In so doing, he would work around one side of a boss while doing some on the area. Then he would overlap some of the area with some work on the edges.

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[1] Lichtner, W. O., "Timestudy and Job Analysis," p. 170, The Ronald Press Company, New York, 1921.

This kind of mixed observation requires some clever timestudy. And when all done, you still have to take apart readings by means of equations. One break in this sort of problem often occurs when, for example, certain castings have no bosses. Of course, all have area and edges. Hence, part of the planning is to get observations of pieces that have no bosses. This will eliminate one of the unknowns.

Studies of such work will result in equations something like those following, where A means minutes per square inch of area of side, E is minutes per inch of perimeter edge, and B is minutes per boss:

$$33A + 28E = .58 \text{ min} \qquad (a)$$
$$28A + 32E = .58 \text{ min} \qquad (b)$$
$$16A + 20E + 2B = .47 \text{ min} \qquad (c)$$

To solve, we can begin with Eqs. (*a*) and (*b*). Our first step is to cancel out one of our terms. To do this, we must make that one equal in two equations. To cancel the A terms, we will multiply Eq. (*a*) by 28 and Eq. (*b*) by 33.

$$\begin{array}{lrcll} & 924A + 1056E & = & 19.14 \text{ min} & (b) \\ & \underline{924A + 784E} & = & \underline{16.24 \text{ min}} & (a) \\ \text{Subtracting:} & 272E & = & 2.90 \text{ min} & \\ & E & = & 2.90/272 \text{ min} & \\ & E & = & .0107 \text{ min} & \end{array}$$

Going back to (*a*) and substituting the value of E, we get

$$\begin{aligned} 33A + .30 &= .58 \text{ min} \\ 33A &= .58 - .30 \text{ min} \\ 33A &= .28 \text{ min} \\ A &= .28/33 \text{ min} \\ A &= .0085 \text{ min} \end{aligned}$$

With values for A and E, we can tackle Eq. (*c*), to find the time per boss.

$$\begin{aligned}(16 \times .0107) + (20 \times .0085) + 2B &= .47\\ .17 + .17 + 2B &= .47\\ 2B &= .47 - .34\\ B &= .13/2\\ B &= .065 \text{ min}\end{aligned}$$

The readings therefore break down into .0107 minute per inch of edge, .0085 minute per square inch of area, and .065 minute per boss.

You can see that this problem has been made simple. That was done purposely. We are interested here only in showing a method. It is one you should know, however, because there are certain problems you can solve in no other way.

PAINT SPRAYING

I have had a number of problems of this type. One was interesting enough to relate. There were three men spray-painting automobile frames that hung on a monorail. The first man painted until the second man pushed the frame he was painting on to the third man. Each did about a third. But each third was indefinite.

The frames had two long side rails. These were fairly uniform. The cross-members differed according to customers' specifications. And some frames had brackets riveted to the side rails.

As emphasized previously, the first step was to follow through a number of different frame types. These studies were to get the total work done, without duplications in part. From these studies, complete standards were set. Then breakdowns were made as closely as they could be. And like the omitted bosses in the casting problem, some studies could be taken on frames that had no brackets. With total standards, some equations were set up. From distinctly separate parts shown on some studies, substitutions could be made to eliminate certain terms. It was quite a struggle. But like most problems, it was solved in time by using lots of patience. I mention patience because the equations are not always true mathematically, as you write them. Consequently, you have to make many trials before you can get all terms solved and proved.

THREE UNKNOWNS

To go further with simultaneous equations, let us work out another practical problem. This one came up in the study of mail delivery routes. It is typical of certain problems that, in my opinion, require the use of equations. You may skip over this second example if you are expert with equations. My advice is to wade through it if you are not sure.

We will start off with four equations. Actually, the rule says that you need as many equations as you have unknowns. That means that three would be enough in this instance.

$$\begin{array}{rcl}
 & \textit{Starting Equations} & \textit{Routes} \\
37 \text{ boxes} + 40 \text{ doors} + 2{,}200 \text{ ft} & = 12.30 \text{ min} & (1) \\
33 \text{ boxes} + 10 \text{ doors} + 5{,}200 \text{ ft} & = 23.10 \text{ min} & (2) \\
55 \text{ boxes} + 50 \text{ doors} + 2{,}600 \text{ ft} & = 15.30 \text{ min} & (3) \\
115 \text{ boxes} + 25 \text{ doors} + 2{,}200 \text{ ft} & = 16.50 \text{ min} & (4)
\end{array}$$

To determine the standard time for each of our three factors, we approach this problem similarly as in the previous castings example. Only here it is a bit more complicated.

PAIRING TO CANCEL

Being timestudy men, we look for an easy way. The easy way here is to cancel out the unknown of "doors." So let's combine Eqs. (1) and (2). Also we will simplify the writing by abbreviating the times for boxes, doors, and feet to *b*, *d*, and *f*.

$$\begin{array}{rl}
33b + 10d + 5{,}200f = 23.1 \text{ min} & (2) \\
37b + 40d + 2{,}200f = 12.3 \text{ min} & (1)
\end{array}$$

To cancel the d terms, we can multiply Eq. (2) by 4 ($40d/10d$).

$$\begin{array}{lrl}
 & 132b + 40d + 20{,}800f = 92.4 \text{ min} & (2) \\
 & 37b + 40d + 2{,}200f = 12.3 \text{ min} & (1) \\
\hline
\text{Subtracting:} & 95b \qquad + 18{,}600f = 80.1 \text{ min} & (A)
\end{array}$$

Next we want to get the combination of Eqs. (3) and (4).

$$\begin{array}{rl}
115b + 25d + 2{,}200f = 16.5 \text{ min} & (4) \\
55b + 50d + 2{,}600f = 15.3 \text{ min} & (3)
\end{array}$$

With this pair, we can cancel the d terms if we multiply Eq. (4) by 2, ($50d/25d$), and then subtract.

$$\begin{array}{lrl}
 & 230b + 50d + 4{,}400f = 33.0 \text{ min} & (4) \\
 & 55b + 50d + 2{,}600f = 15.3 \text{ min} & (3) \\
\hline
\text{Subtracting:} & 175b \qquad + 1{,}800f = 17.7 \text{ min} & (B)
\end{array}$$

REDUCING FURTHER

Our next step is to combine the simplified equations (*A*) and (*B*). In so doing, the easiest way is to multiply (*A*) by 175 and (*B*) by 95. That will make the *b* terms the same. Then we can subtract and have left only *f*.

$$\begin{array}{ll} \text{Eq. }(A) \times 175: & 16{,}625b + 3{,}255{,}000f = 14{,}018 \text{ min} \\ \text{Eq. }(B) \times \ \ 95: & \underline{16{,}625b + \ \ 171{,}000f = \ \ 1{,}682 \text{ min}} \\ \text{Subtracting:} & \qquad\qquad 3{,}084{,}000f = 10{,}794 \text{ min} \end{array}$$

$$f = \frac{12{,}336 \text{ min}}{3{,}084{,}000}$$

$$f = .0040 \text{ min}$$

With one factor known, we can go back and substitute. Equation (*B*) is the easier one to use.

$$\begin{aligned} 175b + 1{,}800f &= 17.7 \text{ min} \qquad (B) \\ 175b + (1{,}800 \times .004) &= 17.7 \text{ min} \\ 175b + 7.2 \text{ min} &= 17.7 \text{ min} \\ 175b &= 17.7 \text{ min} - 7.2 \text{ min} \\ 175b &= 10.5 \text{ min} \\ b &= 10.5 \text{ min}/175 \\ b &= .06 \text{ min} \end{aligned}$$

GETTING THE STANDARDS

Now we have the standards for one *foot* and one mail *box*. Only one more value is needed. We can get the standard for one *door* by substituting our two knowns in any of our starting equations. Let's use the equation for Route 2. It looks like the easiest one to handle.

$$\begin{aligned} 33b + 10d + 5{,}200f &= 23.10 \text{ min} \qquad (2) \\ (33 \times .060) + 10d + (5{,}200 \times .004) &= 23.10 \text{ min} \\ 1.98 \text{ min} + 10d + 20.8 \text{ min} &= 23.10 \text{ min} \end{aligned}$$

Combining all the minute terms together, the sum of the two on the left side, (1.98 + 20.8) or 22.78 minutes is subtracted from the 23.10 minutes on the right side. The result is

$$\begin{aligned} 10d &= .32 \text{ min} \\ d &= .32 \text{ min}/10 \\ d &= .032 \text{ min} \end{aligned}$$

As a result of all these mathematical gyrations, we finally get our answers:

Time for Each	*Standard Minutes*
Mailbox	.060
Door	.032
Foot	.004

CORRECTING OVERLAP

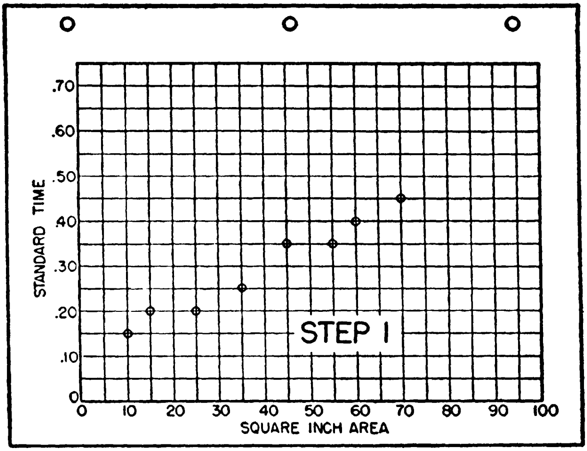
Now, that wasn't so difficult, was it? And the method should be used in cases like this. You cannot get the right answer by simple timestudy without a great deal more work than this method takes. Here is the reason. You know what we mean by acceleration and deceleration. In this timestudy example, the getting under way and slowing down takes place with every door and every mailbox. For that reason, you cannot arrive at the correct standard per foot for walking by ordinary methods. You would have to time separately the approach to and departure from each door and box. But to do that, you would have to "guesstimate" the points where those elements started and stopped. It is more correct and easier, to my way of thinking, to solve this type of problem by means of equations.

By the equation method, these extra times belonging to the boxes and doors are taken out of the walking time. You must make this separation or you do not have correct standard data. Each of these factors must be right when standing alone. Otherwise, you cannot build up a fair time for a route that has not been studied. If you tried to study every one, you would never get done. You know how often they rearrange offices. So get the right answers. Then you can set the standard for a new mail route faster than they can rearrange the desks and offices.

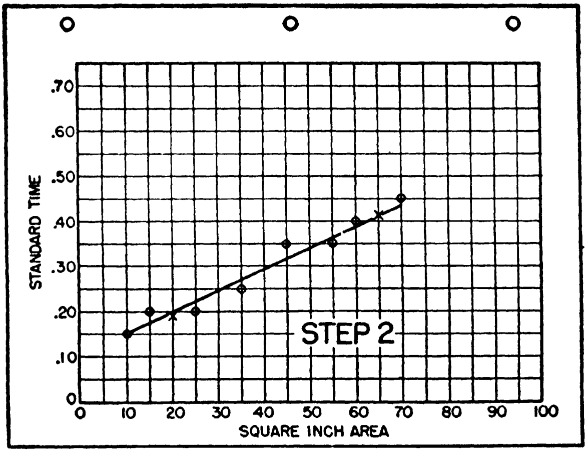
METHOD OF LEAST SQUARES

More equations will probably bore you to tears. But I want to get in one more commonly used method before we sign off. This method is often used in job evaluation. It is called the Method of Least Squares. You may want to use it some time.

Its purpose, as far as we are concerned, is to find the equation of a straight line through a series of points. The line will be located mathematically. That statement may raise a question in your mind. You may ask, "Why not use this method, then, instead of stretching a rubber band as you illustrated in Chapter 8?" The answer is one you have to supply. If each point should be given equal weight in your consideration, then the mathematically determined line is correct. But if you have more "faith" in some of your plotted points than in others, then my suggestion is to draw the line where it should be.



(*a*) Plotted points that are to have a straight line drawn through them.



(*b*) A straight line may be located with mathematical exactness by the Method of Least Squares. The x's are computed locations.

FIG. 29.

You should know, or at least have for reference, the mathematical method. In working an example, we will refer to Fig. 29*a*. There we have plotted eight points. Each one has two factors of location (the ten-dollar word is "coordinates"). These we need to use in our example. Let's line up our points then as

Point	Time	Area
1	.15	10
2	.20	15
3	.20	25
4	.25	35
5	.35	45
6	.35	55
7	.40	60
8	.45	70

Next, we set these as though each were an individual equation of a straight line. You remember the equation we worked with in the early part of this chapter. There we came out with an equation for a straight line as

$$\text{Standard Time} = \text{Constant} + \text{Dimension} \times \text{Value per}$$

Using this for each of the points, we get eight equations. In these we will use A as the Dimension to mean Square Inches.

Point	Equation
1	$.15 = 10A + C$
2	$.20 = 15A + C$
3	$.20 = 25A + C$
4	$.25 = 35A + C$
5	$.35 = 45A + C$
6	$.35 = 55A + C$
7	$.40 = 60A + C$
8	$.45 = 70A + C$

These equations are not like the others we have been using. They are more like the trial type you may start with to solve some problem of your own. We simply wrote these arbitrarily.

But the mathematical procedure will permit us to work these eight into two that we can handle. The procedure requires that we do some multiplying. Two multipliers are used. This will give us two sets of equations. The first multiplier is that of the C

term. It is unity (1) in our equations. Therefore, each of the equations multiplied will be the same afterward as it is now.

OBTAINING TWO EQUATIONS

The second multiplier is the factor with the A term. Here they are different. The results will be quite unlike the present equations.

Equation Number	First Set		Second Set	
	Multiplier	Equation	Multiplier	Equation
1	1	$.15 = 10A + C$	10	$1.50 = 100A + 10C$
2	1	$.20 = 15A + C$	15	$3.00 = 225A + 15C$
3	1	$.20 = 25A + C$	25	$5.00 = 625A + 25C$
4	1	$.25 = 35A + C$	35	$8.75 = 1{,}225A + 35C$
5	1	$.35 = 45A + C$	45	$15.75 = 2{,}025A + 45C$
6	1	$.35 = 55A + C$	55	$19.25 = 3{,}025A + 55C$
7	1	$.40 = 60A + C$	60	$24.00 = 3{,}600A + 60C$
8	1	$.45 = 70A + C$	70	$31.50 = 4{,}900A + 70C$

If we add all these equations together we get

(Eq. 9) $2.35 = 315A + 8C$ (Eq. 10) $108.75 = 15{,}725A + 315C$

These two we can solve simultaneously as in our other examples. We can cancel the C term first. So multiply Eq. (9) by 315 and Eq. (10) by 8:

$$\begin{array}{rrl}
\text{(Eq. 10)} \times 8: & 870.00 = & 125{,}800A + 2{,}520C \\
\text{(Eq. 9)} \times 315: & 740.25 = & 99{,}225A + 2{,}520C \\ \hline
\text{Subtracting:} & 129.75 = & 26{,}575A \\
& A = & 129.75/26{,}575 \\
& A = & .00488 \text{ Min/Sq In.}
\end{array}$$

Substituting the value for A in Eq. (9) we can determine C.

$$\begin{aligned}
2.35 &= 315A + 8C \\
2.35 &= (315 \times .00488) + 8C \\
2.35 &= 1.5372 + 8C \\
8C &= 2.35 - 1.5372 \\
8C &= .8128 \\
C &= .8128/8 \\
C &= .1016 \text{ Min}
\end{aligned}$$

DRAWING THE LINE

The value of C is our Constant Time for 0 Area. And the time answer for A is the slope of the line. This is .00488 Minutes per Square Inch. Hence, our equation will read as

$$\text{Standard Time} = .10\text{ Min} + (.0049\text{ Min/Sq In.} \times \text{Sq In.})$$

To draw in the line, we should compute some points. We have one —our Constant of .10 Minute. But to check, let's figure two more. At 20 Square Inches, the answer to our equation is

$$\begin{aligned}\text{Standard Time} &= .10\text{ Min} + (.0049\text{ Min/Sq In.} \times 20\text{ Sq In.})\\ &= .10 + .098\text{ Min}\\ &= .198\text{ Min}\end{aligned}$$

At 65 Square Inches the Standard Time is

$$\begin{aligned}\text{Standard Time} &= .10\text{ Min} + (.0049\text{ Min/Sq In.} \times 65\text{ Sq In.})\\ &= .10 + .3185\text{ Min}\\ &= .4185\text{ Min}\end{aligned}$$

With these two points plotted x on Fig. 29*b*, we see that our arithmetic checks. The line continued will pass through .10 Minute, our Constant. Also, the line bears a close relationship to the points originally plotted.

EQUATIONS ARE TOOLS

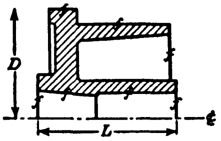
With these several applications of equations, we can conclude. They are representative of the types you need to know for timestudy work. Others are useful, of course. But for the higher forms, you should consult texts written about empirical equations.

Knowledge of equations beyond those explained here is very useful in certain applications. Those beyond are not the simple algebraic array of constants plus variables. Practically all such equations are much more efficiently expressed and used in chart form. Evidence enough is the high cost per standard and the probability of error demonstrated in Chap. 7.

Just the same, there are applications for what I call a "formula." Figure 30 is an example. Even this one can be charted with advantages. This formula was figured backward from curves drawn for total standards. It is a special solution for obtaining the machining standards on very complicated work. It was determined after a number of standards had been set by the usual method of computing the numerous cutting times, and adding in the necessary handling values. The formula was worked out because, as the drawing indicates, the usual method was costly to use for obtaining standards that rarely repeated. The solution was approached after what seemed to be a sufficient number of direct standards had been established. They were plotted. Additional ones were determined to fill in the gaps and measure the extremes. The formula was then determined from the lines representing the graphical solutions.

Plant—A. B. Company
Equip.—Warner & Swasey
Turret Lathe 1A, 2A, 3A.

Date—October 28, 1936
Oper.—Machining Formula 9



Operations: **Turn, bore drill, taper, ream and face**

Limitations: Diameter from 4" to 16"
Length from 2" to 8"
Material MX 17

Formula:
$$\text{Standard} = (11.1 + X) + KD(.301\,D + .946\,L - .00386\,DL + 1.62)$$

Piece up to 60 pounds X = 0
Piece 60 to 200 pounds X = 11.6

Setup = 65.0

FIG. 30. Formula computed to set the standards for a very complex machining operation.

Such a formula has many adaptations as a variation of the usual methods. It should be applied more frequently to make up special solutions. This is advisable when certain types of work occur regularly within an operation that is covered by general working data. Specialized applications are suggested to you by those parts and assemblies drawn by the Engineering Department in the form of typical tracings with blank dimensions. One drawing is made to suffice for a whole line of products. The dimensions are filled in according to the size of a particular part or assembly. Applying this illustration to the problems of standard setting, it sometimes pays to specialize within the general method by using a localized formula for typified operations.[1] Again let me repeat. We want to get the lowest cost possible for each standard set while maintaining accuracy within tolerances. To me that means having knowledge of many ways to solve problems. Then we should use that one best suited to the current situation.

Selected References

DAVIS, D. S.: "Empirical Equations and Nomography," McGraw-Hill Book Company, Inc., New York, 1943.

RUNNING, THEODORE R.: "Empirical Formulas," John Wiley & Sons, Inc., New York 1914.

WORTHING, A. G., and JOSEPH GEFFNER: "Treatment of Experimental Data," John Wiley & Sons, Inc., New York 1943.

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[1] Carroll, Phil, "Timestudy for Cost Control," 2d ed., pp. 174–175. McGraw-Hill Book Company, Inc., New York, 1943.

CHAPTER 12

MAKING ALIGNMENT CHARTS

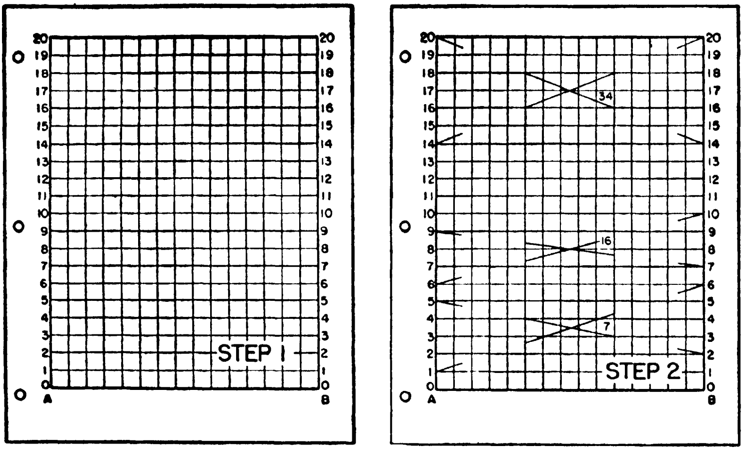
Alignment charts or nomographs are graphical means for solving problems. They are used extensively in many engineering fields. They are especially good for solving complicated formulas. You can find hundreds of them illustrated in the reference texts listed at the end of this chapter.

In timestudy work, they have many applications. You see them used particularly in connection with feed-speed computations for machining time. These appear in texts and magazine articles with surprising frequency. Nomographs are useful when you want to combine a number of additions and subtractions or multiplications and divisions. You can cross over and combine addition with multiplication. That is more difficult. But you will see many examples of the combinations in the texts referred to. Here we will stick to the simpler ones.

SIMPLE ADDITION

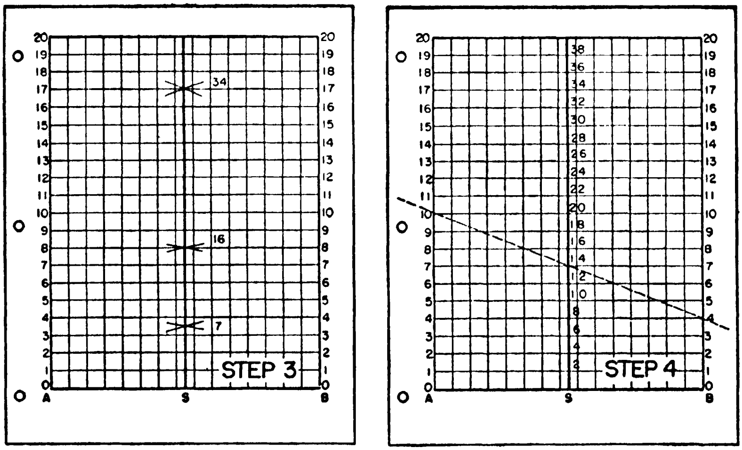
First, let's make up a nomograph to do addition. To start, use any piece of squared paper. Quarter-inch divisions are preferable. Then, along both sides of the page, lay out vertical scales. These should be uniform like 0, 1, 2, 3, 4, . . . , 10. Notice the zero. Both scales should be started with 0 on the same horizontal base line until you become fairly expert in constructing these charts. This is Step 1 (Fig. 31*a*).

Step 2 is to locate the line of sums. This is done graphically. Connect any number on the A scale with any number on the B scale. Draw a short line near the center. Remember the sum of the two numbers you connected. Write it alongside the mark. Then turn your straight edge to connect any other two numbers having the same sum. Draw in a short line to mark the intersection. Repeat this process to get three or more intersections (Fig. 31*b*). This repeating process is done for two reasons. One is to make sure the line you are determining is a straight line. The other is to make sure that your drawing has been done correctly.



(*a*) Lay out uniform vertical scales beginning with the same 0 line.

(*b*) Locate the line of the sums. At the bottom, 6 + 1 equals 2 + 5. Near the center, 6 + 10 equals 7 + 9. At the top, 20 + 14 equals 14 + 20. Only the intersections need be drawn.



(*c*) Three or more intersections should line up vertically. When they do, they locate the straight line of the sums. Draw in the line.

(*d*) With the sum line located you may erase the intersection marks. Then you can lay out the sum scale.

FIG. 31.

Men make mistakes in graphics sometimes. When the intersections all fall in the same straight line, draw it in. Then you may erase the intersecting lines. This is Step 3 (Fig. 31*c*).

Step 4 is to lay out the *Sum* scale. This may be done in several ways. We know what three of the points are. We located 7, 16, and 34 in the example. We can locate other sums in the same way. One easy procedure is to spot the straight edge at one point on the *A* scale as a center. Then move the straight edge vertically along scale *B*, one graduation at a time, to mark off divisions on the Sum scale. Naturally, you shift the center point on the *A* scale to more suitable locations as you progress upward. In this way, you can mark off every division on the Sum scale (Fig. 31*d*).

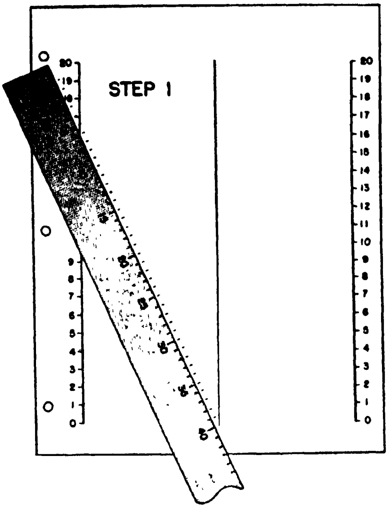
This method of layout is described first because it is an obvious continuation of the basic approach we used in the example. It is given in some detail, however, because you would have to use it under many conditions. Suppose, for example, that our paper were plain and unruled in both directions. What would you do then?

With or without cross-section paper, there is a simpler method often usable. Our example here is an instance. Why can't we take the sums horizontally on each cross line? To illustrate, $1 + 1 = 2$, $2 + 2 = 4$, $3 + 3 = 6$. In this way, you need only write in the sums. When the two scales are equal, the Sum scale is twice either scale.

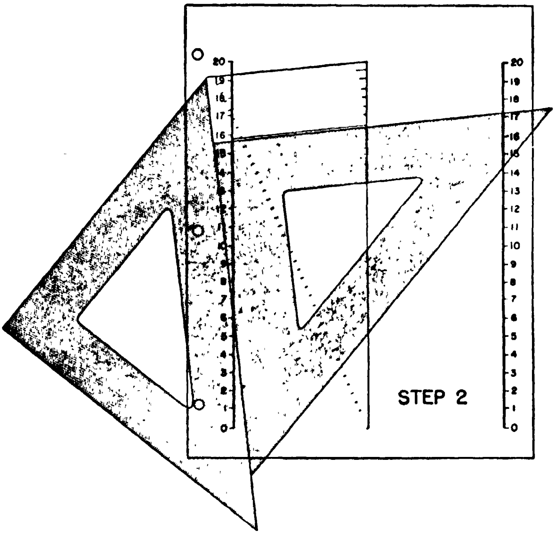
With the example drawn in on Fig. 31*d*, you see how a problem is solved. The line indicates that $4 + 10 = 14$. As you observed in the construction Step 3, the sum sought is obtained whether we add 4 to 10 or 10 to 4. So we have completed a simple nomograph that correctly adds any pair of numbers in two ranges of numbers. But note. We can subtract with this chart. Reversing direction in our previous example, $14 - 10 = 4$. This is a step to remember. There are timestudy problems to solve that require subtraction.

DIVIDING A LINE

A third method is available. We should insert a description of it here because it has many uses. The method is the application of simple proportion executed graphically. It may be used with both uniform and logarithmic scales. We will show the uniform scale projection in some detail (Fig. 32), but only indicate the logarithmic dividing (Fig. 33).



(*a*) Turn a convenient scale to an angle sufficient to allow the required number of divisions to be marked off.



(*b*) Set up triangles so as to connect the last mark with the corresponding division on your scale. Then, holding the parallel, mark off all the divisions.

FIG. 32.

In Fig. 32*a*, you will see a scale turned at an angle. This turning is to bring the desired number of divisions counted off on the scale within the range of the length of line to be divided. In this position, the divisions may be marked off lightly. When the correct number of divisions is laid out, the last one is connected with the corresponding end point on the line to be divided. Carefully, holding this angle with another triangle, you proceed to mark off all the other divisions (Fig. 32*b*).

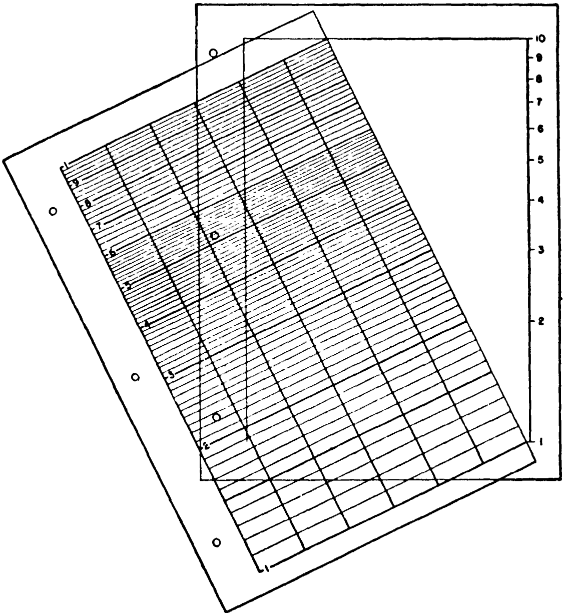


FIG. 33. To get logarithmic divisions, you can use cross-section paper with the desired scale. You will find it convenient to use if you will fold or cut the sheet to bring the scale to the edge of the paper.

The scale is only one method of getting your divisions laid out. In Fig. 33 you will see another device. This shows a way to use graduated cross-section paper to get the same result. Here we used a sheet of semi-log paper to obtain a logarithmic scale. In using such a scale, my preference is to cut off the border of the sheet. Then the scale is right at the edge of the paper. Of course, you can use your slide rule. But that arrangement is not so good. The scale is too far away from the paper for accurate marking.

You might want to get some special paper for this sort of layout. One such sheet published by Codex Book Company[1] has several log scales and a wide range of uniform scale divisions. The paper is No. 3160 Codex Scale Divider.

NOMOGRAPHS FOR MULTIPLYING

Going on a step further with log paper, let's set up a chart for multiplying. To lay out this one (Fig. 34), I turned a piece of semi-log paper to the proper angle. Then I marked off the main divisions. These dots show in a row on the angle. You would want all divisions. Because I intended to make both scales the same, I saved one layout. I set the angle so that the tenth division exactly coincided with a line connecting both 10's, while the 1 on the log paper rested on a line connecting the 1's of the scales. That made one layout of points correct for both scales. Then, setting my triangles so as to get a right angle with the vertical scales, I proceeded to lay out both scales from one set of points.

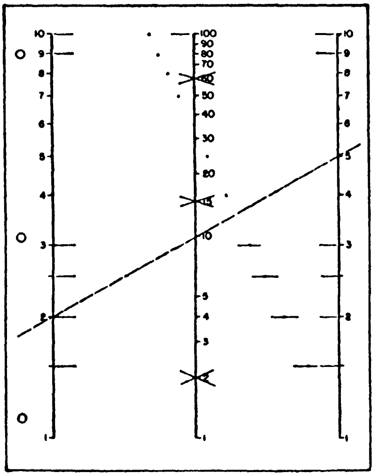


FIG. 34.

Since these scales are logarithmic, we can use them to multiply. They work like your slide rule. That adds lengths together, as our first chart did. But here as on your slide rule, the lengths represent logarithms. In other words, the figures 2, 4, 6, and so on are placed at distances from each other based on logarithmic measures. To illustrate, do a little measuring. On my slide rule, the distance from 2 to 4 is about 3 inches. From 4 to 6, the distance is about 1¾ inches. The differences in logarithms correspond.

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[1] Norwood, Mass.

Number	Log	Difference	
		Log	Inches
2	301		
		301	3
4	602		
		176	1¾
6	778		

So on our scale or on your slide rule, you set numbers together, but actually these are the first cousins appearing in place of the true dimensions—the logarithms. In reality, you are adding logarithms when multiplying. We need not worry, however, about the math mysteries, as long as our chart or slide rule will do the job.[1] And it will, when laid out correctly.

PERFORMING DIVISION

Before leaving this subject, we should recognize two similarities this chart bears to Fig. 31. The first is that products of the numbers horizontally opposite each other are to be found on the center scale. As in Fig. 31, the numbers horizontally opposite are alike because the scales were made identical. The second similarity is the more important. Notice that division is accomplished by reversing procedure. This is the reverse of multiplication similarly as subtraction was demonstrated with the chart made for addition. For example, $10 \div 2 = 5$, or $10 \div 5 = 2$. Thus, you can arrange to perform division when it may be necessary to a solution. But remember, you must use log scales to obtain your results.

UNEQUAL SCALES

You may have realized that our examples have been very conveniently arranged. Your actual problems will not be so simple. For this reason, we should move on to add some complications. As we proceed, the explanations will be confined to addition. Most of our standard setting is by addition. Generally speaking, however, the same approach may be used for multiplying by substituting log scales for uniform scales. If you get lost, review the similarities between the uniform scale nomograph, Fig. 31, and the log-scale example like it, Fig. 34.

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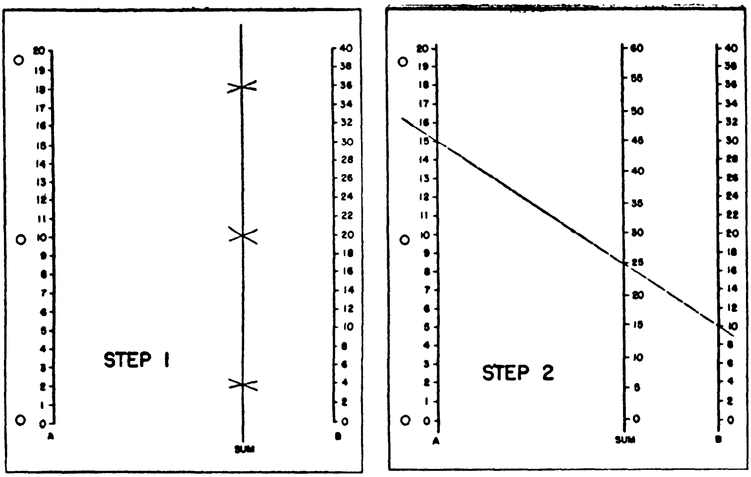
[1] Harris, Charles O., "Slide Rule Simplified," American Technical Society, 1946.

Perhaps the first inconvenience introduced by a practical problem would be unlike scales. So let's tackle that one next. We can start, as in our first example, with two scales laid out vertically. Both begin with 0 on the same base line. We will show the 0's in our example. These could be off the page, however, so long as both scales were started at the same horizontal base line.



(*a*) The Sum line is located by intersections. It falls one-third of the distance from the double scale.

(*b*) The Sum scale is graduated to provide answers to our problem of adding two numbers.

FIG. 35.

In Fig. 35*a*, two scales are shown. One is twice the other in magnitude. Without concerning ourselves about this difference, we proceed as in Fig. 31 to locate our line of *Sums*. Drawing three sets of intersections, we find that the location of the Sum line has moved. It is closer to the scale having the larger values per unit. If you check, you will see that it is located at one-third of the distance between the scales. That is because of the proportions 2 to 1 of the scale values.

As before, you can proceed now with laying out the scale of the

Sum (Fig. 35*b*). You can write in the sums of the numbers that are horizontally opposite. This would give us a scale in 3's—0, 3, 6, 9, . . . , 60. Also you can plot the numbers in between. Remember too, you can set a scale of the divisions you want at an angle (Fig. 32*a*). Then you can mark off the Sum scale by proportion.

THE THIRD VARIABLE

To go further, as with a real problem, suppose we want to add another series of numbers to the sums of two variables. To carry out this step, we will continue with the nomograph just completed (Fig. 36*b*). This has the wider space available on the left side of the page. Generally speaking, there is where we want to place the next Sum line.

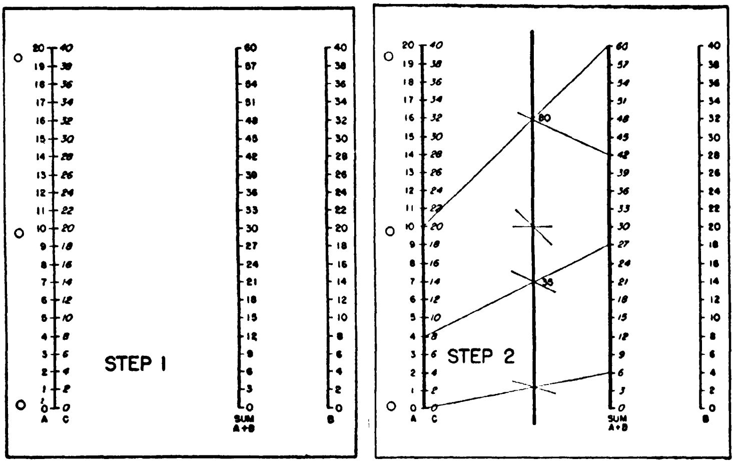
This step of adding another term is a simple one if you will remember one thing. You are now starting a new problem. So far as its solution, there is nothing else on the page but the Sum line just completed and another line representing the third factor. This latter line can be a wholly new one, or another scale laid out on one of the lines already there. Using an existing line is better. The reason is that none of the space will be used up. This will allow the widest practical distance between the scales. Thus the maximum graphical accuracy is maintained. With that explanation, let us lay out our third scale on scale line A. Call this one Scale C (Fig. 36*a*). When this is done, continue with Step 2 to find a new Sum line just as before. Using trial sums, make several intersections to locate the Sum line for $A + B + C$ (Fig. 36*b*). This will fall off center again. Its location is influenced by the ratio of the Sum $A + B$ scale of three values per unit to the C scale of two values per unit.

Having located our final line, we can lay it out with its proper scale (Fig. 36*c*). The same three methods previously described are available to us.

THE FOURTH VARIABLE

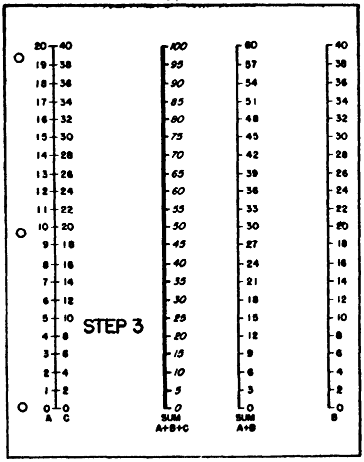
It should be apparent, from our method of adding the *third* variable, that we can go on indefinitely. That is exactly so. Our only limitations are space and confusion. But to be sure this is understood, let's add one more before we call it quits.

Again, so we don't get lost, we will continue with the same example. We will start with the three variables already laid out (Fig. 37*a*). As before, we will conserve space by placing our fourth scale on an available line. The one farthest away is the line of Scale *B*. So lay out the fourth scale alongside Scale *B* and mark it Scale *D* (Fig. 37*b*).



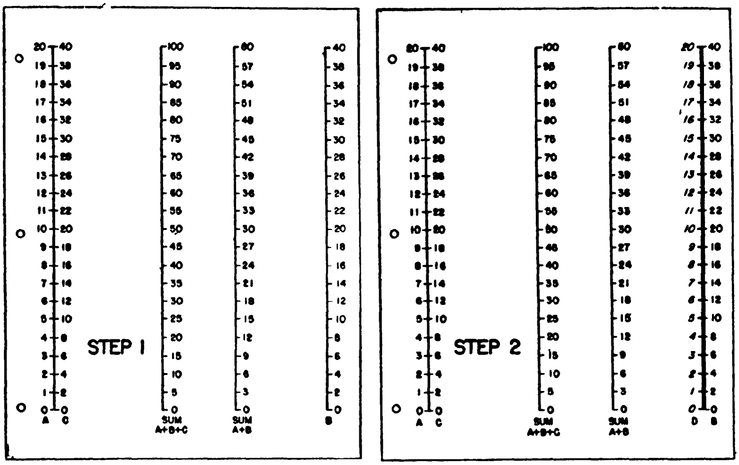
(*a*) Lay out Scale *C* on the inside of the line of Scale *A*.

(*b*) Locate the new line of sums adding *A* + *B* to *C*.



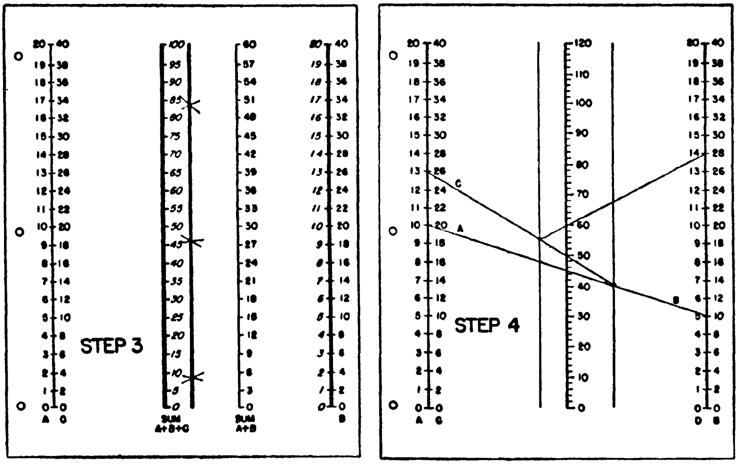
(*c*) Mark off the new scale showing the Sum of *A* + *B* + *C*.

Fig. 36.



(*a*) We begin the addition of a fourth variable with a nomograph completed with three already located.

(*b*) The fourth scale D is added. Usually, this is laid out on a line available farthest away from the scale to be added to it.



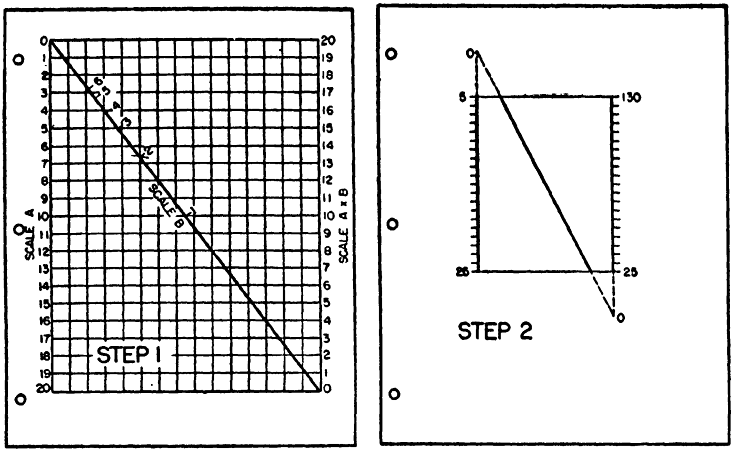
(*c*) The line of final Sum is located by intersections as described earlier in this chapter. Then it is graduated to provide the final Sums.

(*d*) With all lines located and scales laid out, we can erase construction details. The Sum lines for $A + B$ and $A + B + C$ become reference lines. An example shows the application:

$A = 10$ $C = 26$ TOTAL = 60
$B = 10$ $D = 14$

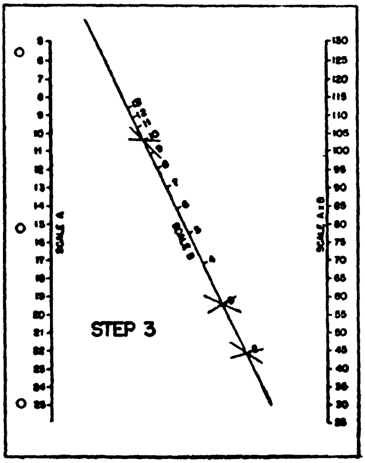
Fig. 37.

Proceed to locate the new line of sums. Forget all the other lines. Look only at the Sum ($A + B + C$) and Scale D. Make several intersections to place the line correctly (Fig. 37*c*). Once it is located, you know what to do. Lay out the final scale of sums. Then check the chart using a number of examples. Be sure to try it out with some extremes of the scale ranges.



(*a*) Uniform scales are laid out in opposite directions. Scale ends are connected.

(*b*) Scale zeros need not be on the chart proper.



(*c*) Multiplying Z chart with scales spread out to suit the problem.

Fig. 38.

Let's complete the chart and do some eliminating. The graduations on the sum lines for $(A + B)$ and $(A + B + C)$ are of no use to us. They are only intermediate answers to our problem. They are construction scales only. We had to use them, however, to get our answer. Now we can erase the scales. Our final chart is shown as Fig. 37*d*. On it is drawn an example to show how the nomograph is used. This practice should be followed with all complex charts. Many like this one will apparently produce wrong answers if not used in the same sequence in which they were developed.

THE Z CHART

We should briefly describe one more type of chart before concluding this chapter on nomograph construction. This one is known as the Z chart. It is one that will enable you to solve multiplication problems with uniform scales. It is particularly useful in cases where you want to spread out a short scale.

Figure 38*a* shows a simple layout of a Z chart. The scales are uniform but progress in opposite directions. The diagonal line is drawn in connecting the two 0's. But note—Scale A is one of our variables, while our other starting scale is our answer, A times B. We must construct the scale for variable B. This is done graphically. An easy way is to pivot on one point of several on Scale A. Then, moving your straight edge to successive points on the $A \times B$ scale, mark off the scale you want to set up.

Carrying on, you will see in Fig. 38*b* a diagram of scales arranged to suit a problem. Only the required portions of the scales are laid out within the confines of the page. This displays my chief reason for including this explanation. The completed chart is shown again in Fig. 38*c* with finished scales. This is a form of solution to remember. It is the most convenient one to use under some circumstances.

With these examples limited to construction fundamentals, we will see how to use them in a few typical problems. These applications will be described and executed in the following chapter.

Selected References

Haskell, Allan C.: "How to Make and Use Graphic Charts," Codex Book Company, Norwood, Mass., 1920.

Kraitchik, Maurice: "Alignment Charts—Construction and Use," D. Van Nostrand Company, Inc., New York, 1944.

LEHOCZKY, PAUL N.: "Alignment Charts—Their Construction and Use," rev. ed., The Ohio State University Press, Columbus, Ohio, 1947.

LIPKA, JOSEPH: "Graphical and Mechanical Computation," Chap 1, John Wiley & Sons, New York, 1918.

PEDDLE, JOHN B.: "Construction of Graphical Charts," McGraw-Hill Book Company, Inc., New York, 1919.

VAN VOORHIS, MERRILL G.: "How to Make Alignment Charts," McGraw-Hill Book Company, Inc., New York, 1937.

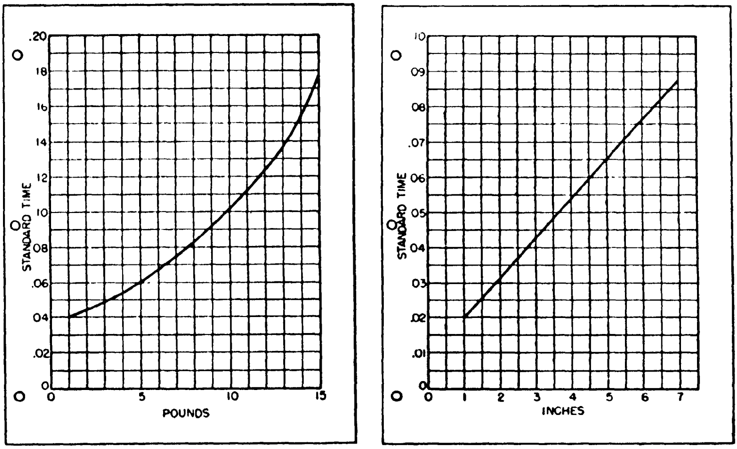
CHAPTER 13

APPLICATIONS OF ALIGNMENT CHARTS

Knowing how to make an alignment chart is one thing. Putting our knowledge to practical use is something else. Now we want to see how we can use what we learned from the previous chapter. We want to work out some applications in the timestudy field.

TWO VARIABLES

The most common problem is the addition of two variables. For our example, we will take two curves (Fig. 39). One shows the Standard Times varying with *Pounds*. The other has its Standard Times related to *Inches*.



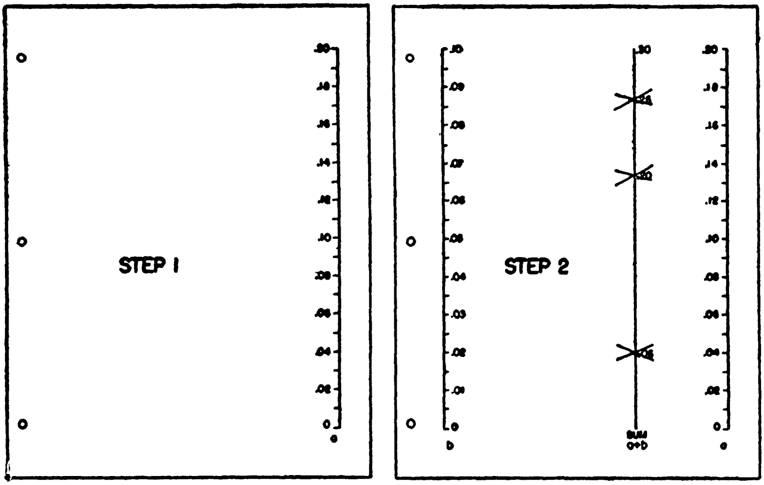
(*a*) A curve of Standard Time dependent upon Pounds. **(*b*) Straight-line curve of Standard Time controlled by Inches.**

FIG. 39.

To combine these, you need to go one step further than in the previous examples. That step is to do some translating into Inches and Pounds. But you start the same way. That is because Standard Times are what you want to add. The translation comes **afterward.**

The first step is to lay out scales. In this, you want to size up your problem. You need the maximum accuracy allowable by the size of paper you use. That should be apparent. You recognize that you get more accuracy on a 10-inch slide rule than on a 6-inch one. If you want even more accuracy, you borrow somebody's 20-inch slide rule.

With a quick look-see at the curves, you note that Curve *a* (Fig. 39*a*) for Pounds has a range of Standard Times from .04 to .17 Minute. That range must be taken care of on one scale. You can lay out such a scale on either of your vertical lines. In Fig. 40*a* it is placed on the right-hand line. It should be placed inside the line, to get it out of the way of your final translating step. The same applies to your other scale for Curve *b*. For this second curve based on Inches, we need a scale ranging from .02 to .09 Minute (Fig. 39*b*). This is about half the range of the other curve, so we can double the scale.



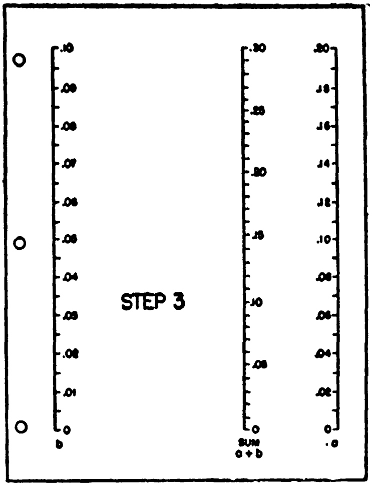
(*a*) Lay out one vertical for the Pounds curve that has a range from .04 to .17 minute.

(*b*) Rule the other vertical scale exactly parallel to the first one. Then lay out the time scale from the Inches curve to include the range from .02 to .09 minute.

FIG. 40. Addition of two variables.

Considering how these look when finished, your question is, "Why not move the zeros off the page? That would expand the scales considerably." You are right. The .02 and .04 should be about where the scales start. The .09 and .18 should be as near the top as possible. This was not done in this case because I wanted to make it easier to portray the subsequent steps.

With scales completed, your next step is to locate the Sum line (Fig. 40*b*). Proceed by making some intersections. After you have fixed the line, then graduate it. Provide for all the sums you will need to set any standard within both ranges (Fig. 40*c*).



(*c*) Graduate the Sum line to provide maximum (.09 + .17) and minimum (.02 + .04) total standards. (*d*) and (*e*)

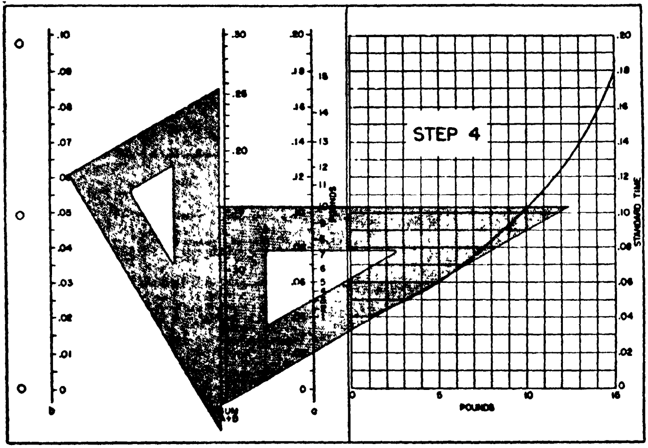
FIG. 40. (*Continued*) Addition of two variables.

TRANSLATING TIME TO DIMENSIONS

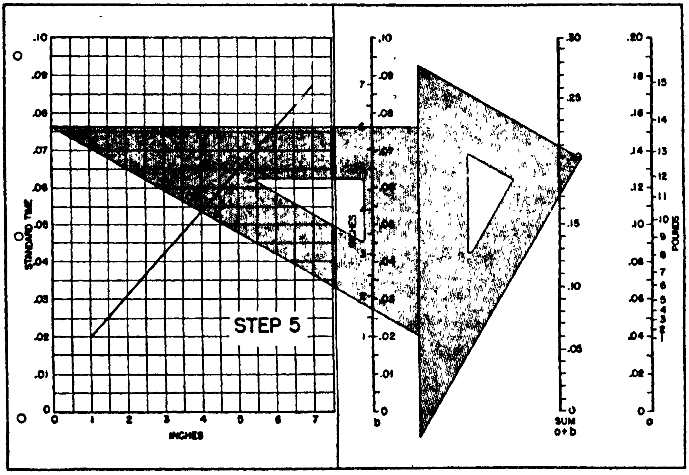
With your answer scale finished, you can begin the translation. You want scales in Pounds and Inches. Those are the dimensions you have in setting a standard. For that reason, then, you want to make your chart into one that can be read directly in those terms. Let's start with Curve *a* and its corresponding scale *a*.

The scale was laid out purposely to correspond exactly with the curve. That means that you can lay the curve alongside the scale and transfer readings. In placing the curve beside the scale, be sure to locate it exactly according to corresponding time standards. This operation is aided by folding under the margin of the curve paper. You can fix it in position with Scotch tape.

By means of triangles, as shown (Fig. 40*d*), or better still a T square, you can make the transfers. Starting at the top, your maximum time standard is where the curve touches the vertical line of 15 Pounds. At the corresponding point on the Time scale, you mark a graduation. Make this mark on the outside of the



(*d*) Place the Pounds curve to exactly align with its time scale. Then transfer Pound equivalents by projecting from points where vertical weight lines cut the curve.

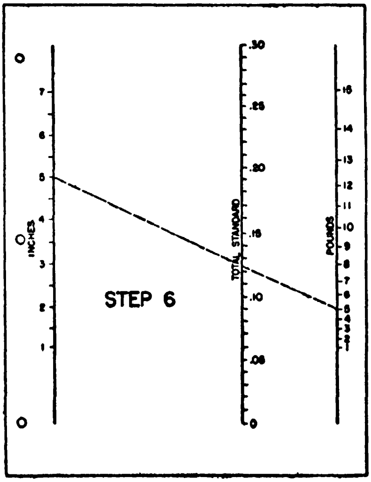


(*e*) Align Inches curve with its time scale and transfer dimensions as in (*d*).

FIG. 40. (*Continued*) Addition of two variables.

scale. Label it 15. Here you see why we laid out the Time scale on the inside. The Time scale is only for construction purposes. It will be erased later.

Continue the graduating of the Pound scale. Move your triangle to the point on the curve where the vertical line for 14 Pounds intersects. Do the same for 13, 12, 11, and 10 Pounds. Mark each Pound division with its weight. Taking each intersection in turn, carefully mark off the complete scale. Number each graduation.



(*f*) **Erase the time scales from the construction lines to complete your nomograph.**
FIG. 40. (*Continued*) Addition of two variables.

With one scale completed, you can work out the second. The method to use is similar. With the Inch scale however, you work from left to right. More care is necessary on this side. Double-check your location. I would lay a straight edge across the curve and mark scale graduations on the right-hand edge. Then you should be able to avoid making an error in location. With the curve placed correctly, you can transfer the Inch divisions. Starting at the top, the first graduation is for 7 Inches. Next below that is 6.5 (Fig. 40*e*). Quarter-inch marks could be inserted if desired. They do not seem necessary because the time standards are so small. Hence, here we show only inches and halves.

With our transferring completed, we can erase the *a* and *b* Time scales. The finished chart will look like Fig. 40*f*, and we can draw in an example showing how to use the chart. Our example here is

Dimensions	Readings, Minutes	
	Curves	Chart
5 Inches	.065	
5 Pounds	.060	
	.125	.125

CHARTS TO DIVIDE

Another application we can make to illustrate is in a chart for computing performance on incentive. In this, we divide Standard Minutes or Units Produced by Minutes on Standard. You might not be interested in making up this particular chart. Even so, it serves to set forth the approach to the solution of this form of problem.

Since this is a problem in division, you need to use log scales. These may be taken from your slide rule, log paper, or scale sheets like the No. 3160 Codex paper mentioned in Chap. 12. Here we have used the Codex paper.

To start, you draw two parallel lines as far apart as your paper will conveniently allow. Then, as in Step 1, Fig. 41*a*, you lay out the scale for your divisor. Either line may be used. Our illustration shows the left scale was used as the starter. Notice also two details about the scale paper. It is turned at an angle to divide proportionally. This step was explained in the previous chapter. In addition, it has its base point outside the sheet of our drawing. The log scale was turned and shifted until it corresponded with the high and low points of the proposed scale. But note—*the horizontal line of unity adopted for this scale automatically determines the base line of unity for the other scale.* That is why it is shown in the diagram.

With the scale placed, your next step is to project the graduations. Again, a T square would provide the best method. We show triangles as a convenient substitute.

When the desired location is found, the log scale should be positively fastened. My personal preference is to paste it down with rubber cement. That adhesive has two advantages. It permits you to slide the scale around and change your mind. Also, it allows you to pull off the scale when your work is done. You can clean up both scale and drawing with a clean rag. The rubber cement will roll up and act somewhat like an artgum eraser. Besides, the pasted scale is free from the obstructions that you'd have if you used something like thumbtacks to fasten it.

MULTIPLYING THE SCALE

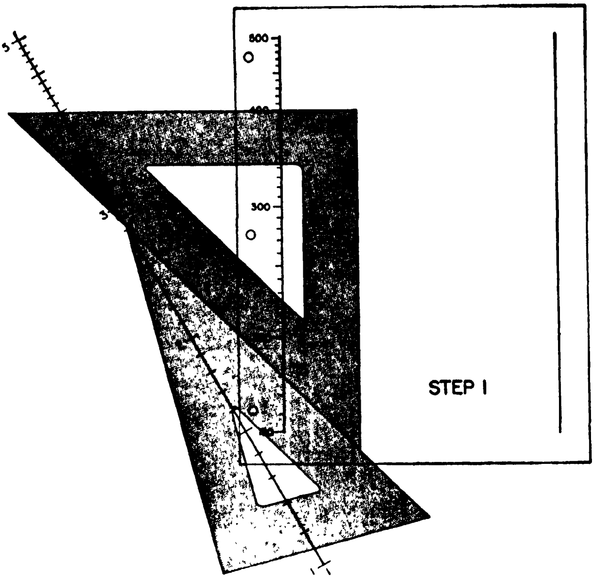
One detail may perplex you. You may ask, "How do you get 500 on the chart when the scale has only 5 on it?" The answer is that these are log divisions like those on your slide rules. You pick up your slide rule and do problems without regard to decimal places except in the answer. There are no decimal points you can use on most of the scales. One time you set 5 as 5,000. The next time, you may use the same 5 as .005. So with log scales, you can multiply or divide to suit your problems. You will notice a different multiplier was used in Step 2. There we wanted 100 to come near the center of the scale. This was brought about by using $^{100}/_{3}$ as the multiplier.

The Step 2 diagram in Fig. 41*b* shows the scale turned at a different angle. In effect, this too is actually using what amounts to a different multiplier. The angle was adjusted to obtain the graduations desired within the extremes of the scale to be set up. Observe that the same base line was used for unity. Then the scale lines were marked off with triangles as indicated. Note that our divisor scale is finished and labeled *Minutes on Standard.*

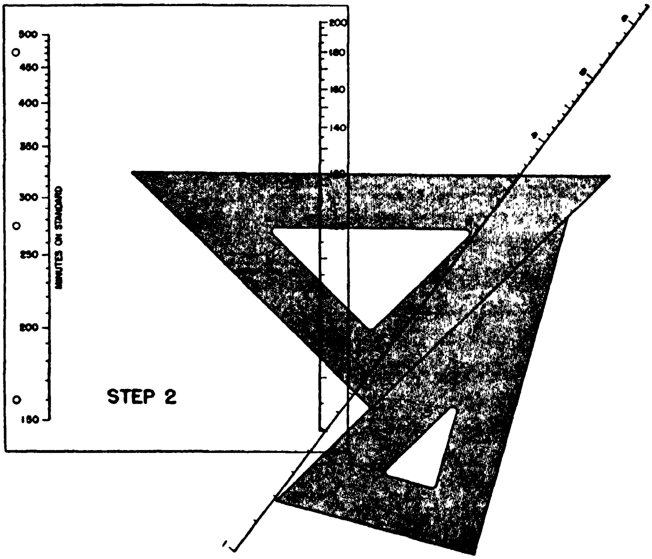
DIVIDEND SCALE

With the divisor and answer scales completed, we can locate the line for Standard Minutes produced. This line is the dividend of our fraction. It falls between the two scales already set. It is located by intersections. This is Step 3 (Fig. 41*c*). Here you will see that it does not fall exactly in the center. That is because one scale is slightly larger than the other.

The next move is to graduate the center scale. It can be done graphically. Many points can be located by using the 100 per cent point on the right-hand scale as a center. If you prefer, you may use any of the prepared log-scale papers. These were shown in Steps 1 and 2. To use on this center scale, you would need to



(*a*) Log scale is turned at an angle to make its divisions proportional to those we want. Notice that unity (1) is located on a base line below the chart.

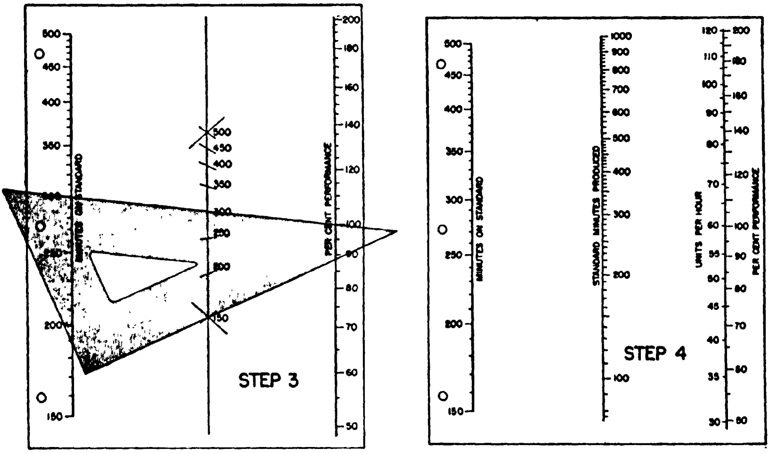


(*b*) The log scale is turned to a greater angle to get in more scale divisions. Notice that unity (1) is at the same base line.

Fig. 41. Computing performance on incentive.

locate two points only. With two points, you can turn and adjust your scale until you get a fitting. That is the way I got these graduations. When they were completed, the intersections were erased and the line marked *Standard Minutes Produced.*

At this point, we have a chart that will compute performance or "efficiency." But my preference is for the measure *Units per Hour.* So, in Step 4, I made another conversion by multiplying (Fig. 41*d*). With 60 Units per Hour being the equivalent of 100 per cent, this change-over was easy. You may prefer this same measure. If you do, then let's back up to Step 2. At this stage, you should put the per cent scale on the inside. It would be used only for construction purposes. It would be erased after the Unit per Hour scale was completed on the outside of your chart.



(*c*) The product line is located by intersections.

(*d*) The center line is graduated. The per cent scale is changed to read in Units per Hour.

FIG. 41. (*Continued*) Computing performance on incentive.

These details are put in here because they describe a fundamental process. This is essentially the same type of conversion we made in our first example in this chapter. You will remember the conversion of two scales. They were laid out in standard times because only in those terms could we add to get our Sum line. After these were laid out, we converted the standard time scales respectively to Pounds and to Inches. Similarly here, we changed the per cent figures used in construction to the Units per Hour that we wanted, to make our answer scale direct reading.

ECONOMICAL LOT SIZE

Another typical application of the nomograph is for the solution of what we call the "economical manufacturing quantity." This problem needs to be solved in every firm that makes product for stock. The answer in simple terms depends upon balancing setup cost against carrying cost. For the solution, there are many formulas. The one we will use here is a simplified equation originally worked out by Bruce Wallace, Vice President and Treasurer, Otis Elevator Company.

To make the logic apparent, we will develop the equation from its fundamentals. First, let's arrange the expression for setup costs.

$$\text{Setup cost per piece} = \frac{\text{Wage rate per minute} \times \text{Setup standard}}{\text{Quantity made per setup}}$$

Suppose we use a wage rate of $1.50 per hour for ease of calculation. This will equal $.025 per minute. Your setup rates may be more or less, depending upon who makes the setup. The rate used here should be reasonably close if the operator makes his own setups. For the other factors, let's use symbols. We can let S stand for setup and use Q to mean quantity made per setup. Then our first expression reduces to

$$\text{Setup cost per piece} = \frac{\$.025 \times S}{Q}$$

To balance against setup cost, we have certain carrying charges. These can include many details of cost. For our purposes, we will limit the factors to interest and obsolescence. Using 6 per cent for interest seems entirely reasonable. The per cent to allow for obsolescence is more a matter of good judgment than it is anything you can calculate. The per cent used should allow for the probable risks due to design changes. The greater the chance of making parts worthless or subject to rework, the higher should be the allowance. As a nominal figure in our solution, we will use 4 per cent. This added to the interest charge of 6 per cent will make a total of 10 per cent for carrying charges. In our equation, these will be divided by two because the full stock is carried for only half the time. The total carrying costs will include, in addition, the factory cost, the quantity run on each setup, and the annual consumption of the product. Arranged in equation form, these several factors will show as follows:

$$\text{Carrying cost per piece} = \frac{\text{Carrying charge} \times \text{Factory cost} \times \text{Quantity per setup}}{2 \times \text{Annual consumption}}$$

Using the 10 per cent charge, C for factory cost, Q as before to represent quantity per setup, and A for annual consumption, our equation becomes

$$\text{Carrying cost per piece} = \frac{.10 \times C \times Q}{2 \times A}$$

The carrying cost per piece should equal the setup cost per piece at the economical lot size. On that premise, our two equations are equal to each other.

$$\frac{\$.025 \times S}{Q} = \frac{.10 \times C \times Q}{2A}$$

Cross-multiplying to clear the denominators, we have

$$.025 \times S \times 2A = .10 \times C \times Q \times Q$$

Changing sides and combining terms, we get

$$Q^2 \times .10C = .05A \times S$$

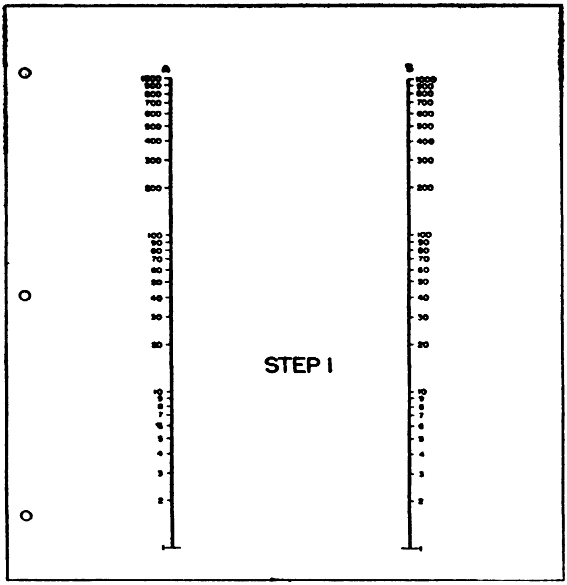
$$Q^2 = \frac{.05AS}{.10C}$$

$$Q^2 = \frac{.5AS}{C}$$

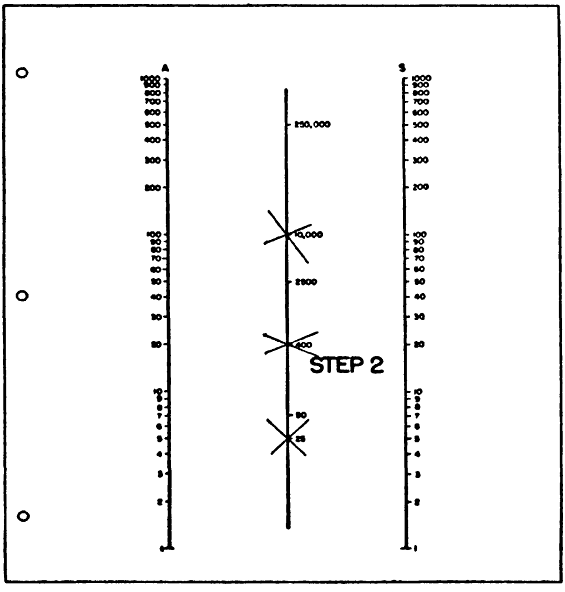
To get our final answer for Q, we must extract the square root. But in working out this problem graphically, we are better off using the equation as it stands.

Step 1. Starting with the factors for Annual Consumption and Setup Units, we lay out a scale for each. These start with the same unity base line and have log divisions because we are multiplying $A \times S$. The ranges of both scales are taken as 1 to 1,000, being ordinary limits. This requires the use of a three-cycle log scale. When laid out, our scale will appear about as shown in Fig. 42*a*.

The multiplier of .5 can be taken into account here or any subsequent stage. In this case, it seems easier to apply it to

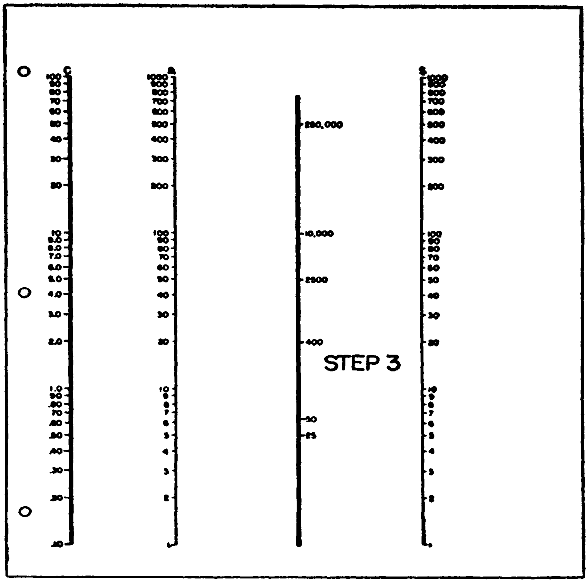


(*a*) Scales for Annual Consumption (A) and Setup Standard (S) are laid out **exactly** parallel and with three cycles of log divisions to cover a range from 1 to 1,000.

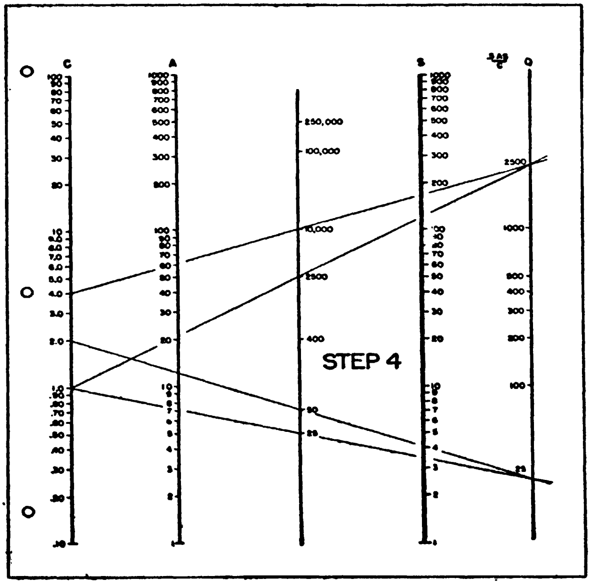


(*b*) The line of products of A × S is located. Here, because our scales are equal, it falls exactly on center between them. This is only a reference line and so you need locate only a few points for construction purposes.

Fig. 42. Application of the nomograph for the solution of what we call the "economical manufacturing quantity."



(*c*) A scale is added for Factory Cost. Its location can be most any place, including placement along either of the two scale lines already drawn. Here it is placed separately to have it show up clearly.

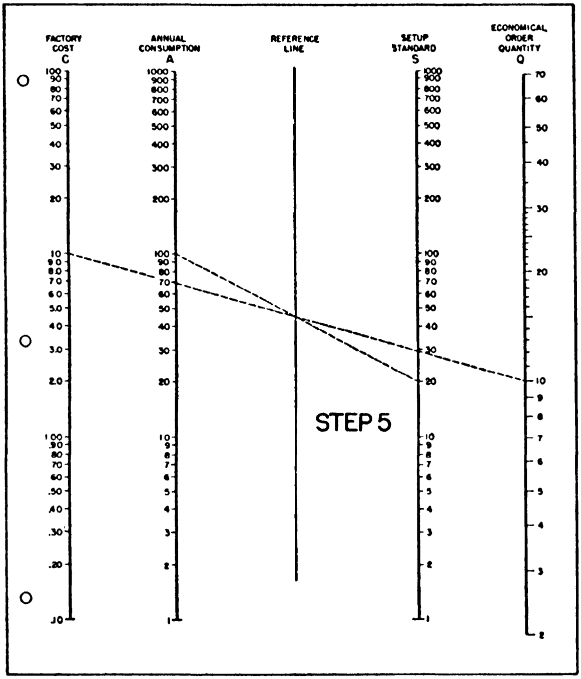


(*d*) Dividing reference-line values of A × S by Factory Cost values will locate the answer line. Points on this line are not final results. They must be converted by multiplying by .5 and taking the square root.

Fig. 42. (*Continued*) Application of the nomograph for the solution of what we call the "economical manufacturing quantity."

the answer scale. The reason is that we need to convert the answer scale anyway, by extracting square root. Hence, we can make both conversions in the same step.

Step 2. Having laid out the two scales, we proceed to locate the Product line. This should lie exactly in the center between our scales. The reason it should be in the center, if you will remember, is because our two scales have the same graduations. With the Product line located, it can be graduated lightly (Fig. 42*b*). Not all divisions need be made, however. This is only a reference line. All we need are a few points located and marked for use in the next calculation. Whatever divisions we do lay out will be erased later.



(*e*) The answer scale for Lot Size is graduated. All construction figures are erased. All scales are labeled and an example drawn to show how the chart is to be used.

FIG. 42. (*Continued*) Application of the nomograph for the solution of what we call the "economical manufacturing quantity."

Step 3. Next we need a scale for Factory Cost. It can be located in any convenient place. It can be laid out on the opposite side of either of the existing scales. Either location would be equally accurate, because both lines are the same distance from the reference line. In Fig. 42*c* it has been set up separately. This makes the line stand out. Also, it permits us to place a title over it later to help reduce the risks of misinterpretations. With a location adopted, we can go ahead on the scale layout. This too will be logarithmic. The range chosen was $.10 to $100.00. The finished scale is shown in Fig. 42*c*.

Step 4. Having completed the scale for Factory Cost, we can use reference points on our Product scale to locate the line of answers. This will fall as a separate line also. It will be near the scale for setup standards. Of course, it is found by intersections determined by dividing point values on the reference line by Factory Cost figures. When located, as with the Product reference line, we need only a few answer points (Fig. 42*d*). The reason is that these answers have to be further modified.

Up to this point, we have worked with full values for Annual Consumption, Setup Units, and Factory Cost. At this stage, we have a conversion to make. It is to be somewhat like that made in the first example in this chapter. The difference is that here the conversion is mathematical. We must incorporate the .5 factor that appears on the right side of the equation and then take the square root. Our scale values are .5 times the square of the economical lot quantity.

To accomplish this step, we can work out the final conversions for the several answer points spotted on the line. These will show us what sort of a log scale we will need to use in dividing the line. Then we must select a log scale that approximates our range of answers. Placing it alongside as in Figs. 40 and 41, in the front of this chapter, we can turn the scale to the proper angle. Once located exactly, the scale divisions are projected to our final answer line.

Step 5. In the final stage, we want to erase the construction details and letter the scales. Then we should check our chart in several places and draw in an example to show how it is to be used. In Fig. 42*e*, the factors assumed are

Annual Consumption = 100 pieces
Factory Cost = $10.00
Setup Standard = 20 min

The chart shows an answer of 10 pieces as the proper lot size. We get 10 pieces by solving the equation, $Q = \sqrt{\frac{.5AS}{C}}$. Our solution is correct.

SOLVING PROBLEMS

The detailed explanations of the three examples in this chapter and those in the preceding chapter should give you a working knowledge of nomograph construction. Certain of the illustrations were chosen to depict a range of application.

Nomographs are not very difficult to make for the solutions of problems related to timestudy. They are useful in many fields in connection with our work. They provide mathematical solutions through graphical methods. By their very nature, they cannot be as accurate as mathematics itself. But usually, the accuracy is well within the necessary limits. In many instances—the last example is typical—only relative accuracy is necessary. And it can be increased, as with a slide rule, by enlargement.

The nomograph has special values, like other graphical methods. It can be used to get answers quickly. It has many uses, particularly when there are large numbers of computations to make. These can be obtained at low cost by means of charts such as we have worked out in this chapter. Probably, as a rule, more advantages accrue when the calculations involve multiplication and division.

The nomograph is a working tool that should be understood by timestudy men. They should be equipped to choose this method of solution when it best fits the circumstances. In that respect, it is like any tool that would be part of a skilled man's kit. Only when the tool kit contains all the tools can he do his job most effectively.

CHAPTER 14

MULTIPLE CURVES

The family of curves is quite common in timestudy work. It is the form of data that results from the analysis of a compound variable. But families of curves may also be built up through computation. In this chapter, we want to take up the graphical combinations of both kinds.

FACTORED CURVES

We will start with the simple curve (Fig. 43). To such a curve, we might want to add a constant. Put the other way, we might have a problem involving one or more curves and one or more constants. These constants would need to be in a total. For that reason, we must add them in at some stage of chart construction. Here, we will add them to the curve. This method has been chosen because it is easier to portray the application factors other than simple addition.

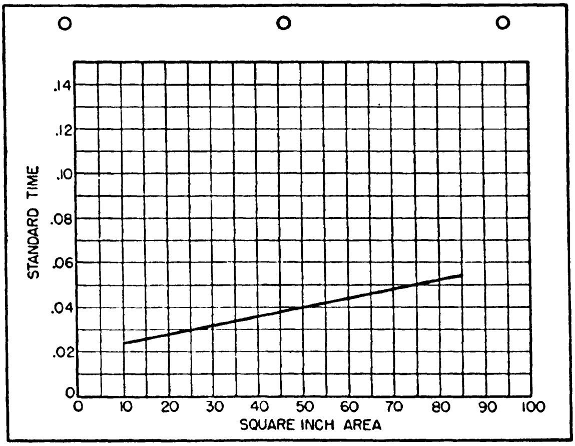
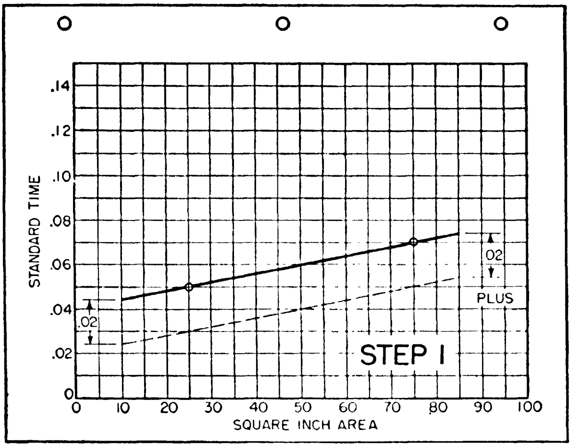
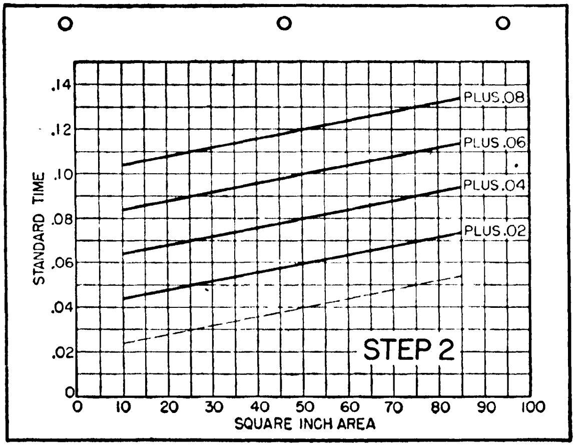


FIG. 43. A simple straight-line curve to be factored in several ways in subsequent illustrations.

In Fig. 44*a*, we have shown the addition of .02 Minute to our starting curve. To locate a new line, two points were plotted. Only two are necessary because the line is straight. At 25 Square



(*a*) The original curve with the constant .02 minute added.

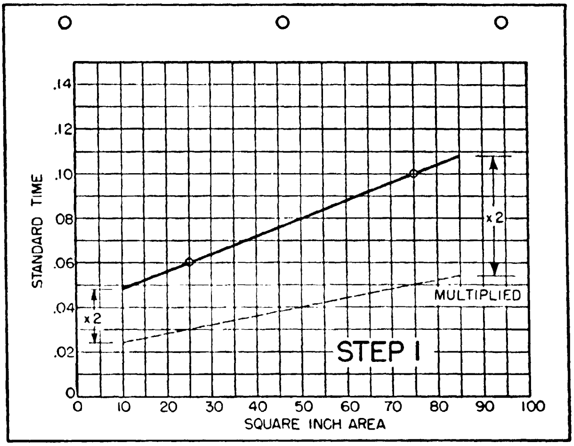


(*b*) The original curve with the four different constants, .02, .04, .06, .08 minute added.

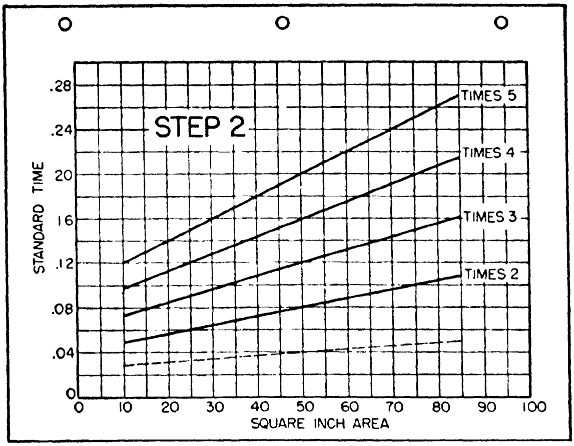
Fig. 44.

Inches, our original curve reads .03 Minute. To this value of .03 Minute, we add the constant of .02 Minute and the sum .05 Minute is one point on our new curve. Likewise at 75 Square

Inches, the .05-Minute curve reading plus the constant of .02 Minute equals .07 Minute, the other point. Through these two points, our new line is drawn.



(a) A Standard Time variable multiplied by two.



(b) The same data variable multiplied by a series of factors.

Fig. 45.

In Fig. 44b, we have gone a step further. Including the first one just explained, we have added four different constants. Similarly, as in Fig. 44a, two points were obtained for plotting each of the new curves. When completed, we have a family of curves representing one variable plus four different constants. Such an example in timestudy could arise if we think of packaging. The standards could be similar to those for sealing cartons of different sizes plus writing on different combinations of identifying order numbers. I recognize that 2 by 5 inches would be too small for a carton. You can laugh, and then we can go on to our next type of factoring.

MULTIPLYING FACTORS

Quite often, we have problems in standard setting that require the multiplication of a curve reading by one or more factors. To illustrate this operation, we have prepared Fig. 45. In Fig. 45*a*,

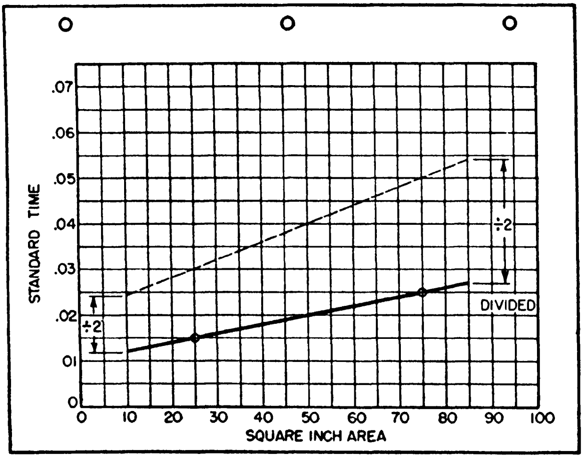


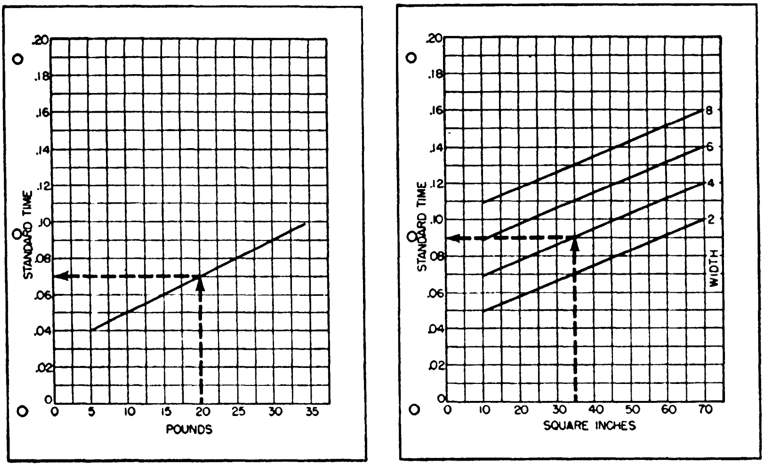
Fig. 46. A curve may be divided by one or more factors.

our original curve is shown as a dotted line. The new line to be located is to show two times the curve readings. Every curve reading is to be doubled. To plot this new curve, only two points need be located, however, because the original line is straight. One is taken at 25 Square Inches. There the curve reads .03 Minute. Using .03 × 2, we get .06 Minute. This is plotted. The other point at 75 Square Inches is the .05-Minute curve reading, and .05 × 2 = .10 Minute as plotted. Then our line is drawn.

In Fig. 45*b* the multiplication has been extended. The scale has been changed, however, in order to include the several curves.

Here we show the starting curve dotted as well as the results obtained by multiplying it by 2, 3, 4, and 5. Such examples occur frequently in standard setting. They appear in many instances where an element is repeated. Also, they happen when quantity comes in—provided, of course, that the time for each unit remains unchanged.

Occasionally, we have need to divide instead of multiply. That operation is performed in a like manner. Figure 46, drawn to a larger scale, shows an example.



(*a*) A curve for Standard Time based on Pounds that is only part of the operation standard.

(*b*) A family of curves related to Square Inches that shows part of total operation standard.

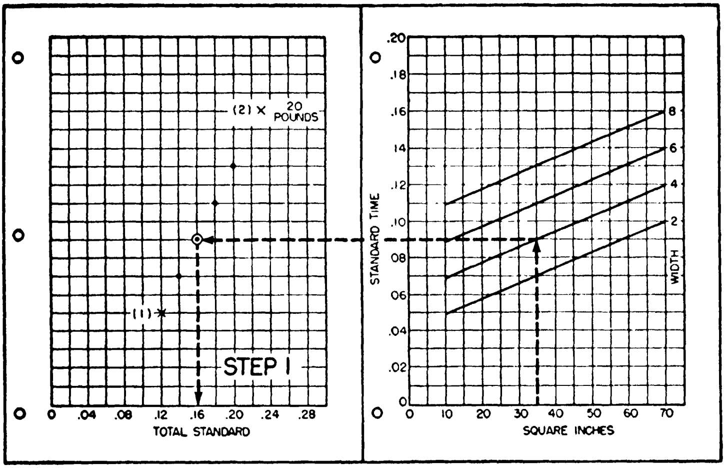
FIG. 47. Two different variables may have to be added in standard setting.

TWO VARIABLE ADDITION

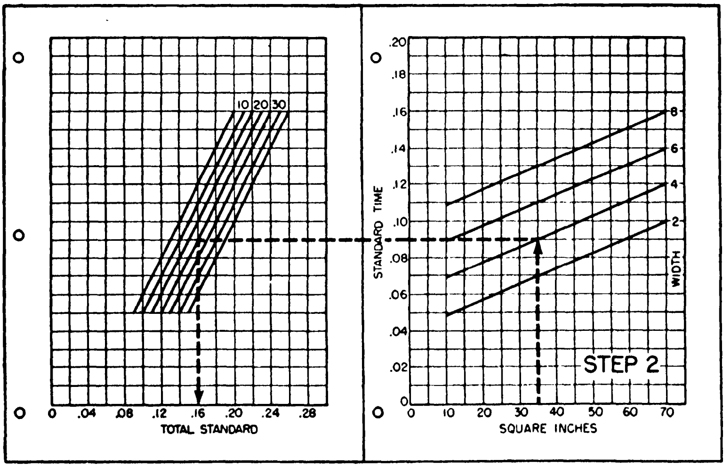
Going to a little more complication, we have two sets of curves to be added. Those shown in Fig. 47 can be used as examples. Suppose you had to add element values from these two curves in setting standards. If constants were to be included also, they could be treated as already outlined.

A reading for 35 Square Inches on Curve 4 is .09 Minute. And the value for 20 Pounds is .07 Minute. The total you want to get is .16 Minute. So let's go about obtaining that total by graphical addition. In starting, we will build around the more complicated variable for Square Inches. It has four curves already in place.

In reading this curve, you select the Square Inch point on the base line that corresponds with your standard requirement. You move upward to the curve for the Width. Then you go left to the Standard. That means your problem of adding another vari-



(*a*) Place another sheet of cross-section paper alongside the chart so you can do some experimenting to get the total standard.



(*b*) In the same way as you located the 20-Pound line in (*a*) you find the lines for other weights.

Fig. 48.

able might be solved by continuing to the left somewhere beyond the first curve sheet.

Let's place another sheet of cross-section paper alongside (Fig. 48*a*. On this, we can do some experimenting. Initially, we need a time scale. Set that up along the bottom edge. Make it extensive enough to include the full range of possible standards. Your least one is .04 Minute (5 Pounds) plus .05 Minute (10 Square Inches on Curve 2). Your greatest is .10 Minute (35 Pounds) plus .16 Minute (70 Square Inches on Curve 8).

With your scale laid out, your next step is to get to the .16-Minute total standard you want. This you could do, if you interrupted the east-west line of motion through the two charts. So why not set up a road block at that point? The circle shows where.

But one point is no solution. Let's see if you can find a line that will mark the turn. First, we know that there are three more readings we can get on our base curve for 35 Square Inches. They are for Curves 2, 6, and 8.

Dimensions	Readings from Curves, Minutes			
	2	4	6	8
35 Square Inches........	.07	.09	.11	.13
20 Pounds..............	.07	.07	.07	.07
Total Standard..	.14	.16	.18	.20

Let's spot all these points. They belong at the intersections. These corners are where horizontal lines extending from your base-curve readings meet lines vertically through the totals you must get. This is figuring backward from the answer, if you prefer.

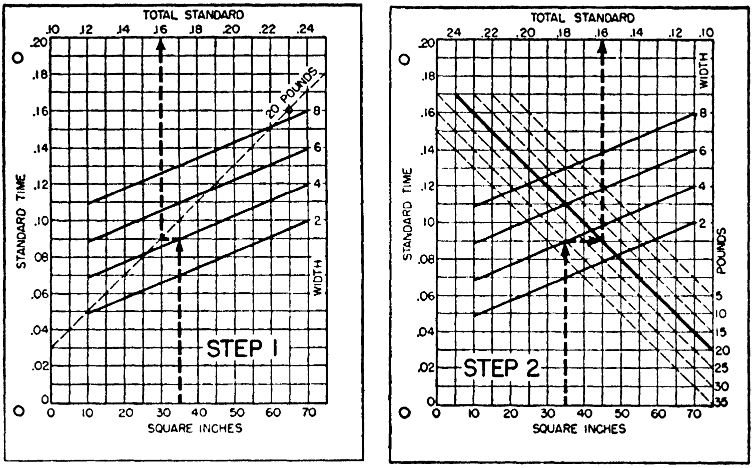
These points should show up in one straight line. But continue one step further. Get two more points. These will give an added check. But they are necessary to indicate the length of the line you must draw. The length must include the extremes in standards. These are (1) the lowest reading for the 2-inch Width curve, and (2) the highest reading for the 8-inch Width curve. These points show as x's in the diagram.

With these points, you have located only the line for 20 Pounds. There are other weights. The next step is to find their lines.

Proceeding in the same way, you locate the several you need. These will show up similarly as indicated on Fig. 48*b*.

CONSERVING SPACE

As you look over your finished work, you might say, "Why so much paper?" You might then try to put both sets of lines on one page. One such attempt is illustrated in Fig. 49*a*. You will notice, however, that there is some confusion created, because the 20-Pound line is in the same general direction as the other lines. This can be remedied. Simply reverse the direction of your scale of Total Standard. This will cause the lines to fall in the opposite direction (Fig. 49*b*). This is a point to remember:



(*a*) The first attempt at consolidation results in a line for 20 Pounds not too distinctive.

(*b*) By sometimes reversing the scale of Total Standard you can get curves more nearly at right angles to each other.

FIG. 49.

1. *Reverse your scale when practical in the attempt to place families of curves at right angles to each other.*

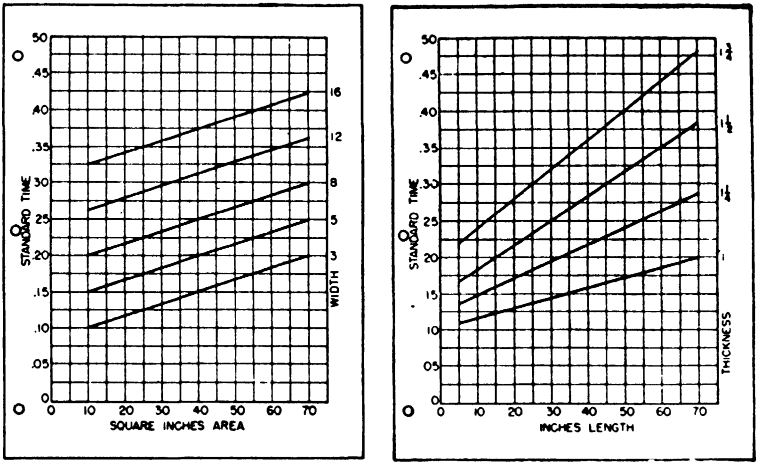
In this same general way there is another rule to follow.

2. *Shift scale locations to minimize concentrations of curves.*

One other change was made in completing Fig. 49*b*. The closeness of the lines for weight in Fig. 48*b* was overcome. This was accomplished by spreading out the scale. This way of clear-ing up a part of the confusion resulting from multiple curves somewhat contradicts Rule 2 just stated. You must strike the best balance you can between it and the rule that follows. The third rule given here is a restatement in part of one given in Chap. 8:

3. *Spread out scales to reasonable maximums for the purpose of separating curves of one family.*

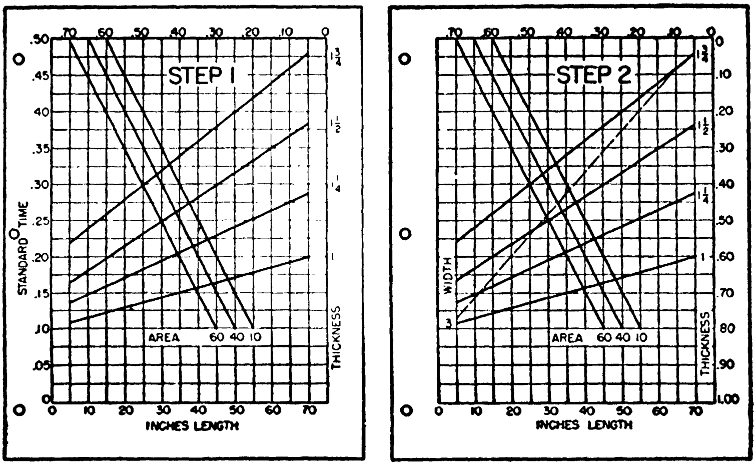
Combining two or more families of curves can be a fairly simple task or a very difficult one. So much depends upon what kind of families they are. Those having interdependent variables are the difficult ones to cope with graphically. They require plotting against two scales simultaneously. They are best treated by first getting their equations. Then usually, you can work with one variable at a time as the foregoing explanation has pointed out.



(*a*) (*b*)

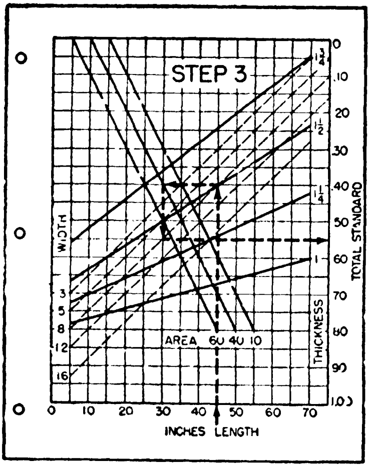
FIG. 50. Two families of curves to be combined.

Sometimes, you may be able to choose a sequence in procedure that simplifies the combining. That is the case here. We can avoid unraveling the complex family by using it as the starting base. This choice is possible only because one of the two families is not complex in its make-up. Therefore, right off, let me say that the explanation to follow is not general. It will not apply to any two families. You will see what I mean by examining Fig. 50. In this illustration, the curve family for Length is like the previous example. But the family for Area is simplified. Its lines are parallel. They do not diverge. *Caution!* Do not



(*a*) Area lines are located and drawn in.

(*b*) The base line for 3-Inch Width is located and drawn.



(*c*) Increments for Width are added from the base line for 3-Inch Width. Diagram line shows how to read the completed chart.

Fig. 51.

try to follow through the procedure given here if both families have diverging sets of curves.

This explanation is added to what has gone before to include one more variable. In reality, it is an added set of constants. Let us begin with Fig. 51*a*. It is like the chart completed in Fig. 49*b*. It provides the sum of values from the Length curve when added to readings from only the bottom curve in the Area family. Lines for 10, 40, and 60 show. More lines should be added. They are omitted to avoid confusion. These three lines were set up exactly like those in our previous example. They were laid out as though there were only one curve for Area. This was done to establish a foundation. It was a necessary step to separate the Square Inch variable from that of Width. Remember these families have two variables each.

Remembering our previous example, you will recall that our chart was complete at this point. It resembled this example here. It was worked out to add only one curve. That is just what we have now. Therefore, to go to the next step we must put in a line to indicate our next right-angle turn. But that line cannot add any to the time. The time standard is the correct total at this stage for the 3-Inch Width line.

Add a line, then, that will make the right-angle turn and yet not change the answer. Such a line will bisect the angle between the two scales, if they are equal. They are, in our setup. This line is shown dotted in Fig. 51*b*. It is the base line for our final step.

Since our Area differences have been taken care of, the remaining factor is Width difference. With a base line for 3-Inch Width, we need only to add to this for width differences. The spread between the 3-Inch and 5-Inch Width curves is .05 Minute. So a line drawn parallel to the 3-Inch Width curve and .05 Minute away from it to add that much time standard will place the 5-Inch Width line in the correct location. The 8-Inch line is also .05 Minute away from the 5-Inch line, or .10 Minute away from the 3-Inch Width curve we used as a base line. The 12-Inch and 16-Inch lines have .0625-Minute spacings. This spread is used to space these two curves similarly as the 5- and 8-Inch curves were plotted. Thus, the complete family is located. The finished chart is shown as Fig. 51*c*. On this, is drawn a road map to show how to use it. The standard is worked out as follows:

Dimensions	Readings, Min	
	Curves	Chart
45-In. Length × 1½-In. Thickness	.30	
40 Sq In. × 8-In. Width	.25	
	.55	.55

APPLICATIONS

With these examples, the general approach should be understood. Some more ideas will be developed in our next chapter. There, by means of some ordinary timestudy problems, we will attempt to show ways to apply these principles.

The family-of-curves method is a good one to use in certain instances. You can see how, with a little practice, it can afford a fast solution to some complex problem. That is its important advantage. It is quick. It is inexpensive. You should get better acquainted with this method of combining data. It can save time for you.

CHAPTER 15

TYPICAL CURVE-FAMILY EXAMPLES

You will be interested in the solutions in this chapter. At least some of them should intrigue you. I hope so, because this approach is a good one to know. It is a quick way to solve certain types of complex problems.

The curve-family method, as I have named it, is not well understood. But just think back into the previous chapter. Remember how you could get hundreds of answers from one line drawn? All that was involved to get it was spotting a couple of points. In most cases, that is all the time it takes. Now for a timestudy application.

ADD, DIVIDE, AND MULTIPLY

Our first example involves the addition of two variables with the result multiplied and divided. The standards have been altered, but you can think of it as applying to a packaging operation. The four factors involved are

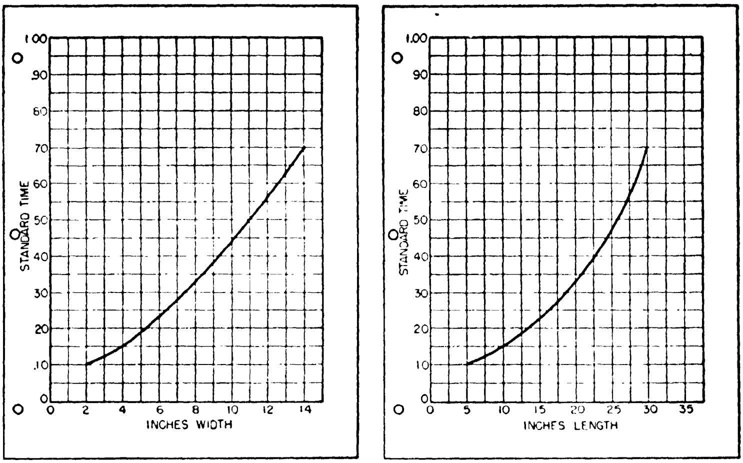
1. *Length* of carton (inches)
2. *Width* of carton (inches)
3. Number of *Items* in cartons
4. Number of *Bands* on carton

Figure 52 shows the curves for Length and Width standards. The equation carries the multiplier 2 that changes $L + W$ to perimeter. As carried out here, there can be 1, 2, or 3 Bands around the package. And in our problem, we may have 4, 6, 8, or 12 Items in the package. This factor for items is a divisor in our problem because we want to get the standard time per item.

Step 1. Your first move is to lay out two scales (Fig. 53*a*). The Length scale covers the range of standard times shown on the curve. This is from .10 to .70 Minute, taken from Curve *B*, Fig. 52. It must be laid out in time units to start with because we can add, and later multiply and divide, only in time values. Eventually, we will translate this time scale to equivalent units of Length. Then, in order to add these standards to those for Width, we must set up a vertical scale to provide for the Sum.

This has a maximum of .70 Minute from Curve *B* plus .70 Minute from Curve *A*. So you must lay out a scale to include 1.40 Minutes at the high extreme. You can label this scale $L + W$. Then you won't get lost.

Step 2. With the two scales all set, your next step is to locate the first line (Fig. 53*b*). Any one of several will do. Let's start with the low one. The least reading on Curve *A* is .10 Minute for 2-Inch Width. If this is added to values from Curve *B* for Length it will increase them by .10 Minute. Consequently, if you add .10 Minute for 2-Inch Width to .10 Minute for Length, you get .20 Minute total. This is one point on the line. It is placed over .10 Minute for Length and opposite .20 Minute $L + W$. Now, you can use the same procedure for a point near the maximum. In the example, .10 Minute for 2-Inch Width plus .60 Minute for Length equals .70 $L + W$. Plot this point on the vertical line through .60 Minute for Length opposite .70 Minute on the $L + W$ scale. These two points locate the line. You can draw it through them. Mark it "2 Inches" to distinguish it from others.



Curve *A* Curve *B*

FIG. 52. Our problem in standard setting involves the two curves shown above plus some factors. The total standard is based on the equation

$$\text{Standard} = \frac{(\text{Width} + \text{Length}) \times 2 \times \text{Bands}}{\text{Number in Carton}}$$

where

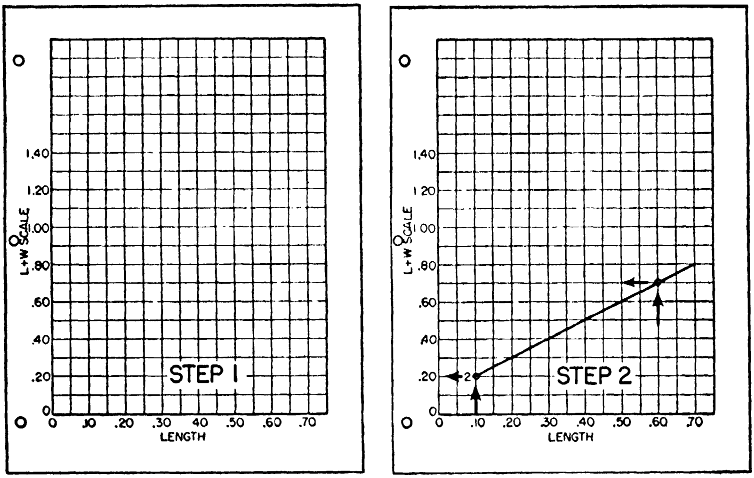
Bands = 1, 2, or 3, and Number = 4, 6, 8, 12.

Step 3. In the same way you located the 2-Inch line, you establish the others (Fig. 53*c*). The number of lines to be drawn depends upon the accuracy you want to maintain. For convenience and clarity, only a representative number are shown here. These were set up as readings from the labeled verticals in Curve *A*. To illustrate, the reading for 4-Inch Width is .15 Minute. Adding .15 + .10 = .25 Minute as one point. This is plotted over .10 Minute for Length and opposite .25 Minute on *L* + *W*. At the other point, .15 + .60 = .75 Minute. This second point is plotted over .60 Minute for Length and opposite .75 Minute on *L* + *W*. Then the line is drawn. At the extreme, Curve *A* reads .70 Minute for 14-Inch Width. Adding, .70 + .10 = .80 Minute, your first point, with .70 + .60 = 1.30 Minutes as the other. The line through these two is the top one. All the others are located in the same way. Each is labeled as it is drawn in, to avoid mistakes and back-checking.

Step 4. Your next step is important. That's how it appears to me. I say that because it has been difficult for trainees to ge around this next corner. After they get by this hurdle, the rest seems easy. To help you, I have erased the bottom time scale for Length. In its place have been laid out the Length dimensions (Fig. 53*d*). By making this change, I hope to keep you from getting confused. You must forget the erased time scale. That step is completed. You are going on to the next step.

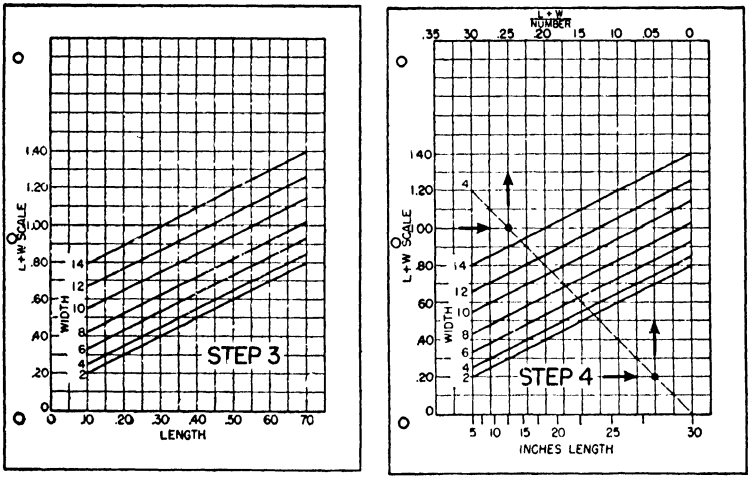
In preparation, you want to lay out a scale at the top for your next set of answers. These will be the results from *L* + *W* divided by *Number*. The factors of Number are 4, 6, 8, and 12. These will give extremes as .20/12 and 1.30/4. The least value on *L* + *W* divided by the greatest Number is the maximum. The latter, .32 (1.30/4) is the only one you need concern yourself about, because there is sufficient space for your scale. And write it in backward to get a cross-trend to your lines. Label the scale (*L* + *W*)/Number.

Starting with four items of Number, figure points for plotting your first line. Using 1.00 on *L* + *W* as the first one, you get 1.00/4 equals .25 Minute. Plot this opposite 1.00 Minute on *L* + *W* and under the .25-Minute division on the top scale, for (*L* + *W*)/Number. Follow the same procedure for a second point. Using .20 Minute divided by 4, you get .05 Minute. That locates a point opposite .20 Minute on *L* + *W* directly under .05 Minute



(*a*) Lay out horizontal scale to cover the range of Length and vertical scale for Length + Width.

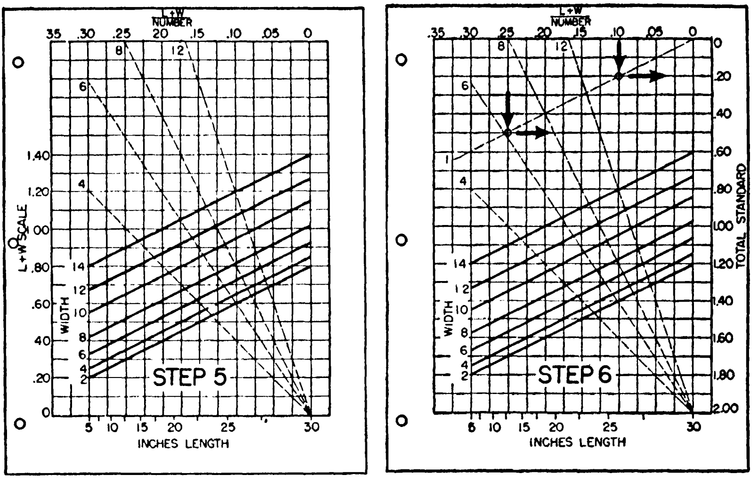
(*b*) Locate two points on first line of family by adding .10 for $W = 2$ to separated times for L.



(*c*) Locate other lines in the family, one at a time by adding times for specific Widths to conveniently located times for Length.

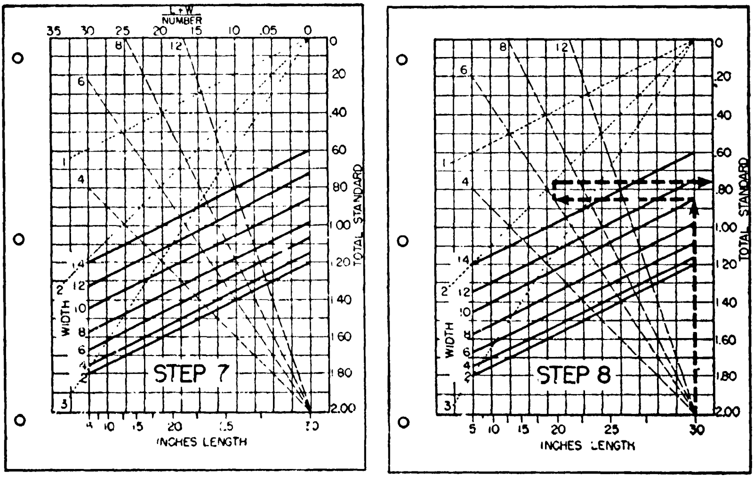
(*d*) Arrange a scale for $\frac{L + W}{\text{Number}}$ at top of chart, in reverse direction to throw new family across the one already drawn in.

FIG. 53.



(*e*) Locate family for Number by dividing convenient $L + W$ Scale divisions by the several factors for Number.

(*f*) Lay out scale for final standard that includes full range at 90 degrees from previous scale.



(*g*) Locate lines for Band groups by multiplying constant 2 × Bands by scale readings for $\frac{L + W}{\text{Number}}$.

(*h*) Erase construction scales. Check the chart in several extreme examples. Draw in a road map.

FIG. 53. (*Continued*)

on the top scale. Now you can draw in your line and mark it 4 for Number.

Step 5. Continue with the process of dividing and locating (Fig. 53*e*). Using 6 as your next number, find two points. An easy one is 1.20/6, equaling .20 Minute. Another is .60/6 or .10 Minute. Make two dots. One is opposite 1.20 Minutes on $L + W$ and under .20 Minute on the top scale. The other is opposite .60 Minute and under .10 Minute. Draw in the line. This and other lines in this family will stand out better if you use long dashes to distinguish them. And you can complete the lines for Numbers 8 and 12 in the same way. Be sure to label each line correctly.

Notice that all these Number lines converge at 0-0. This is obvious when you think of it. Zero divided by 4 or any other number results in 0 as an answer. This simplification assists in plotting. It means that you need compute only one point for all your lines. But be cautious. First, you do not always have 0-0 so conveniently located. Second, I advise two or more point locations to check. When they all fall on a common line you know two things:

a. You have a straight line.
b. You have made no mistakes.

Step 6. If you have successfully negotiated that corner, we can go on under less tension. Your next step should be easier. This one involves the concluding calculation of multiplying. You must provide standards for one, two, or three Bands. Also, there is the constant multiplier of 2 to change $L + W$ into perimeter. So remember, your multipliers are 2 × 1, 2 × 2, and 2 × 3.

First, you can lay out the final scale, another 90 degrees from the top scale. Here again I have erased the $L + W$ scale so you can't look backward. And your new scale is to be the *Total Standard.* It will range from a low of (.20/12) × 2 × 1 to a high of (1.30/4) × 2 × 3. These are the extremes used in Step 4 multiplied by the constant factor of 2 and the extremes of 1 and 3 Bands. The approximate minimum is .02 × 2 equals .04 Minute. As maximum, you have .32 × 6 or 1.92 Minutes. Therefore, a scale from 0 to 2.00 Minutes will be needed. Write that scale along the right margin and label it Total Standard (Fig. 53*f*).

Now you are ready to locate your first line in this last family. Let's start with the multiplier of 2 × 1. Using .25 Minute as one location, your answer is .25 × 2 or .50 Minute. Plot this under .25 Minute and opposite .50 Minute on your final scale. Likewise, take .10 × 2 equals .20 Minute and locate it under .10 Minute and opposite .20 Minute Standard. Draw in your line. Label it 1 so there will be no mistakes of wrong identity.

Step 7. Follow the same procedures for multipliers 2 × 2, and 2 × 3. When these lines are located, you can draw and label them. (Fig. 53*g*). You might use dotted lines for this family. And again, notice that this group converged at 0-0 for the scales applying to this family.

Step 8. Your diagram is completed except for the finishing touches (Fig. 53*h*). First, you should check it to see that it is correct. Second, you should draw in a road map to show how it is to be used. And don't get lost here. You must follow exactly the same sequence in solving a problem that you used in building your solution. If you do not retrace your steps in the same way, you might get almost any answer.

Let's set a standard to check the chart. Suppose you have these conditions:

Dimensions		Reading	
		Curves	Chart
Length	30	.70	
Width	10	.44	
Bands	×2		
Number	÷6		
$\frac{(.44 + .70) \times 2 \times 2}{6}$	=	.76	.76

This is the example drawn in on the chart. Hurrah! It works.

MACHINE TIME CHART

Now we should try another chart that solves a familiar problem, "What is the cutting time?" It's a problem that is as old as the hills. But sometimes I think we get across an idea best with a familiar illustration. So here goes. Keep in mind that this chart is straight calculation. That may be just the use you may want to make of this form of solution.

$$\text{Time} = \frac{\pi}{12}\,\frac{\text{Diameter} \times \text{Length}}{\text{Surface Speed} \times \text{Feed}}$$

Everything in the equation is in inches except Surface Speed. The Speed is in surface feet per minute. That is how the 12 gets in the equation. The symbol π is equal to 3.1416 and is included because Diameter must be converted to circumference. Taken together, $\pi/12$ becomes .2618 in number form. We will use .262 to distinguish this number from a time standard, although .26 is close enough. Now, you can tackle the equation in several ways. You can work through the multiplication in the numerator. Then you can do each division in sequence. You can include the constant multiplier (.262) first, last, or in between. My preference is to alternate, as on a slide rule. I would divide after multiplying. It holds the scales to lower ranges. In most cases too, I would be inclined to take care of the constant at the outset.

Step 1. With that explanation, let's lay out the first two scales (Fig. 54*a*). These are placed at right angles as before. The bottom scale is made to cover the range in Diameter you want to include. The vertical scale is worked out the same way, only here, you figure .262 × Maximum Diameter × Maximum Length you will need. In the example, we used 10 Inches as Maximum Length.

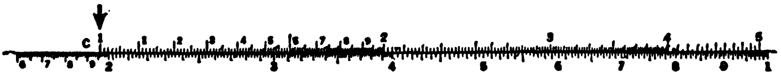
Step 2. Having calculated the extreme of the vertical scale, it was laid out (Fig. 54*b*). Then we proceed to locate one line. Using the extreme point just calculated for the 10-Inch Length gives us one point on that line. The top point equals $.262 \times 7.5 \times 10$, or 19.65. At another point, $.262 \times 1.5 \times 10 = 3.93$. Of course, $.262 \times 0 \times 0 = 0$. But if you are not any better mathematician than I am, you will not rely on this zero business. It's all right, though, after you prove it.

Step 3. Having located the line of Maximum Length, you can spot the rest of the group (Fig. 54*c*). In doing so, I would use a constant multiplier. Set it up on your slide rule.

a. Divide $\pi/12$. The approximation is .262.

b. Multiply by 7.5, the Maximum Diameter, to get 1.96 constant.

c. Set 1 to 1.96 and read off the points for each Diameter.

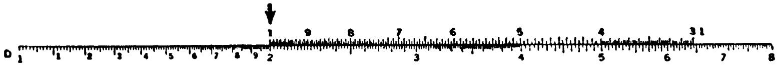


Diameter	Point	Diameter	Point
1	1.96	6	11.78
2	3.92	7	12.74
3	5.89	8	15.71
4	7.85	9	17.67
5	9.81	10	19.64

Plot these along the 7.5 Diameter vertical because 7.5 was the multiplier. Then draw in each line and label it with its corresponding Length.

Step 4. Next you should divide, if you want to hold the scales to more reasonable limits. So consider the factor of Surface Speed. Figure the limits of a scale you will need. This is computed by using the lowest Speed you expect to use. In the example (Fig. 54*d*), 18/60 equals .30, and that was set as the extreme. The scale was written backward to 0 because we want the lines to fall across those already drawn. Plotting the .30 result gives one point on the line for 60 Speed. Dividing 6 on the .262 × *D* × *L* scale by 60 gave another point. Drawing in the line, we see that it goes through 0-0.

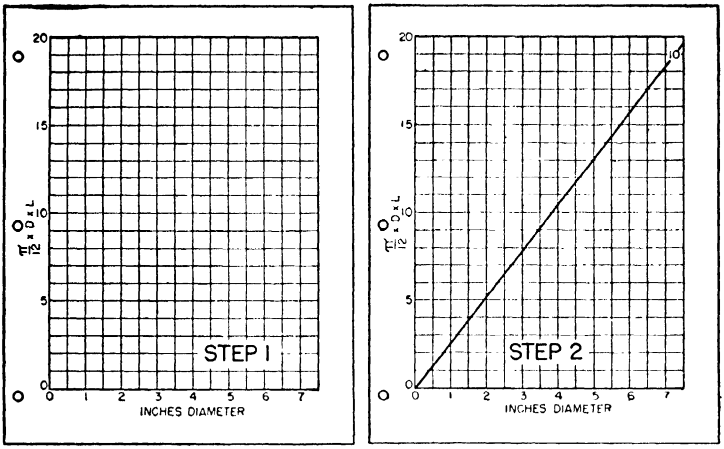
Step 5. Again, you may set your slide rule. Use a red scale if you have one. Set the red 1 on 20, and read off the points.



Plot these along the 20 line (Fig. 54*e*). These will be the upper ends of your lines. The other end will be 0-0. Lacking a red scale, you can divide the Speeds into any convenient divisions on the left scale—for example, $^{14}/_{70}$, $^{16}/_{80}$, $^{18}/_{90}$, $^{20}/_{100}$, $^{12}/_{120}$, and $^{15}/_{150}$. With these points, you can locate the lines and draw them. Label each Speed line.

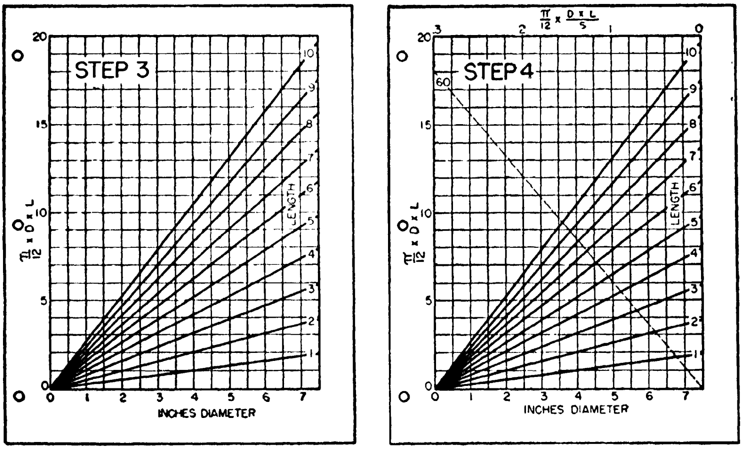
Step 6. Only the Feed remains to be plotted. And you need another scale at 90 degrees that will be the answer in Time. If your lowest Feed is .010 Inches, then the maximum will be .30/.010 or 30 Minute. The .30 is the extreme determined in Step 4. The cross-section paper happens to work out for a limit of 40 Minutes. Dividing convenient divisions on the top scale by the Feeds will locate the lines (Fig. 54*f*). On the .30 line, are spotted

.20/.005 In. = 40 Min .30/.015 In. = 20 Min
.30/.010 In. = 30 Min .30/.020 In. = 15 Min



(*a*) Lay out a bottom scale to include the range of Diameters. Then set up a vertical scale for $\frac{\pi}{12}(D \times L)$.

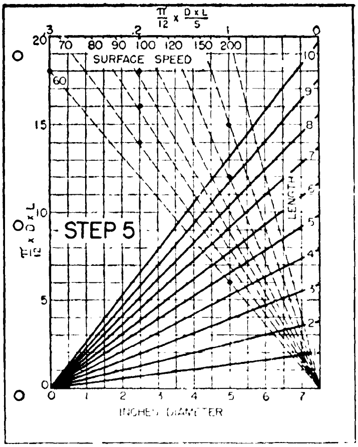
(*b*) Multiply your maximum Diameter by maximum Length × $\frac{\pi}{12}$ and spot the end of the line. Locate another point and draw the line.



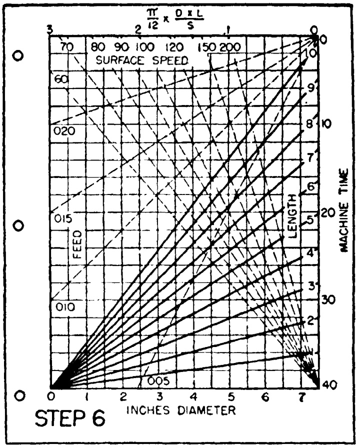
(*c*) Using a constant of $\frac{\pi}{12}$ × Maximum Diameter, multiply by all different lengths to locate ends of lines.

(*d*) Set up a new scale at the top equal to left scale divided by Surface Speed. Locate the line of Minimum Speed.

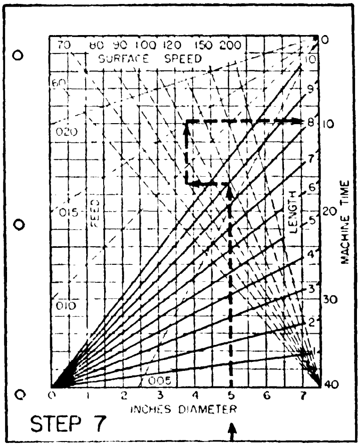
Fig. 54.



(e) Divide Speeds into convenient divisions on left-hand scale to spot points on lines.



(f) Lay out Time scale at 90 degrees and make it long enough to solve any problem in the range. Then locate lines for Feed. Divide top scale by Feeds to be used.



(g) Check the chart by several extreme examples. Draw in one to show how to use it. Erase construction scales.

Fig. 54. (*Continued*)

All lines are then labeled. More Feed lines would be inserted in a solution you would work out for everyday use. These four serve only to illustrate.

Step 7. All our factors are now included. Our next step is to check our chart. Work out several examples. Use some that get away off in the corners to check the extremes. When you find that the chart is correct, then erase your construction scales (Fig. 54*g*). Use one of your check examples as the basis for a road map to show how the chart is used. The one shown is

$$\text{Time} = \frac{\pi}{12} \times \frac{\text{Diameter} \times \text{Length}}{\text{Surface Speed} \times \text{Feed}}$$

$$= .262 \times \frac{5 \times 9}{80 \times .015}$$

$$= 9.83 \text{ Min}$$

CONVERTING CHARTS

One more example may be an aid to further understanding. You may encounter a similar problem sometime. You may have a problem in timestudy that requires the conversion of one set of measures to another. In such cases, the family of curves may be the best form of solution. One such problem arose in a chemical plant. We had the Handling standards. Also, we knew how many gallons were handled in starting the process. But we had to find out how many of those gallons were left at the end of the operation. The change took place through either diluting or concentrating a basic chemical.

As a specific application, it may hold no interest at all for you. Yet, if you will examine the equation that underlies it, you may see how to use it for your own purposes. If we let X stand for final gallons and I for initial gallons, the equation is

$$X = I \times \frac{(\text{Final Sp. Gr.} - \text{Initial Sp. Gr.})}{(1.0 - \text{Final Sp. Gr.})}$$

The Initial Specific Gravity and the Final Specific Gravity were specified on the manufacturing order. Those were engineering requirements just like sizes on a drawing for some part to be fabricated.

A problem like this breaks down into three parts. They are

1. Concentrating Specific Gravity
2. Diluting Specific Gravity
3. Changing gallon amounts

Step 1. To approach the solution of this equation, we need to know the probable limits. This is the first question to raise in any graphical method. To get this, we compute the range of answers likely to result from the Specific Gravity multiplier. In some cases, you may go beyond the actual limits to gain some graphical advantage. I refer to such advantages as accrue from the use of the 0-0 convergence of lines brought out earlier in this chapter. Here we have such a simplification when the Gravity factor becomes 1.0 or unity. So we can lay out two scales at right angles to each other. One is for Initial Specific Gravity. In Fig 55*a* this shows at the top. It could have been placed on any one of the other three sides. Down from it is the ascending scale for the factor.

With a series of test examples, you can spot points on the lines to be drawn. One point on each line is known. It is the Initial Gravity. Computing another point for each is all that is required. After you have found that all lines meet at 1.0-1.0, on the base line, then no further computations are necessary. By way of easing the initial problems of computation, you may use some algebraic manipulations. If you take a point on the scale like .5, you can set that equal to the factor. The sign of the .5 is minus for "Concentrating." If G_1 is the Initial Specific Gravity and G_2 is the Final Specific Gravity,

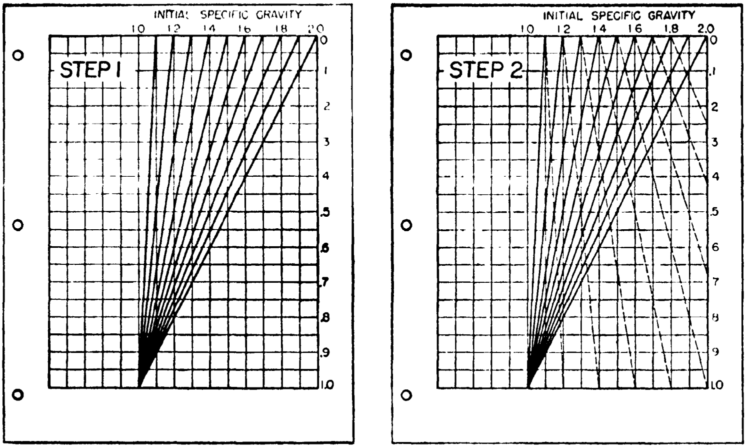
$$-.5 = \frac{G_2 - G_1}{1.0 - G_2}$$

Multiplying by the denominator, you get

$$\begin{aligned} -.5 + .5G_2 &= G_2 - G_1 \\ -.5G_2 + G_2 &= .5 - G_1 \\ .5G_2 &= .5 - G_1 \end{aligned}$$

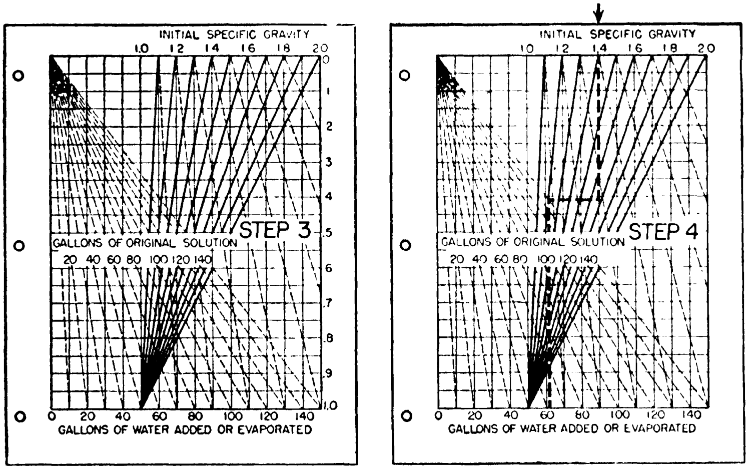
$$G_2 = \frac{.5 - G_1}{.5}$$

$$G_2 = 1.0 - 2G_1$$



(*a*) Compute the extremes for the Specific Gravity factor and lay out a scale. Locate the family of curves for concentrated solutions.

(*b*) Develop the family for the diluted solutions. Locate specifically or by applying a simplified equation.



(*c*) Plot the curves for Gallon volume. These will converge at 0 and be at full value on a line for unity factor.

(*d*) Dress up the final chart. Check it and draw in an example of "How to Use."

Fig. 55.

For locating a point, let's use this with a Specific Gravity of 1.4:

$$G_2 = 1.0 - 2(1.4)$$
$$G_2 = -1.8$$

This result means that the line of 1.8 Specific Gravity should cross the Specific Gravity vertical of 1.4 when the factor of .5 is the result of solving the algebraic formula. You can use such a simplified expression to locate several points all along the line of one factor. By drawing in a few, you find the 1.0-1.0 intersection on the base line. Then this family can be completed.

Step 2. Finding the second family is much the same. With diluting, the change is from a higher to lower specific gravity. That changes the sign of the scale to plus. In working out the equation for simple computation as for concentrating but using the base-line factor of +1.0 instead of −.5, you get

$$G_2 = .5 + .5G_1$$

For an Initial Specific Gravity of 1.6, the diluted Specific Gravity at the factor 1.0 is

$$G_2 = .5 + .5(1.6)$$
$$G_2 = 1.3$$

Using this approach, you can locate base-line points for most of the Specific Gravity lines. The remainder can be calculated individually. Thus the second family is plotted (Fig. 55*b*). The lines are drawn in dashed or dotted to distinguish them from the concentrated gravities.

Step 3. Having established the factorial results for change in Specific Gravity, we can apply them to the volume in Gallons. Remember, this is change in volume we are computing, not total volume. The changes in volume are expressed in the construction factors at the right. These can be used as percentages to set up the final scale. For example, when the factor is .5 and the Initial Gallons 80, the change in volume is .5 × 80 or 40 gallons. The same applies for .2 factor or any other. Consequently, when the factor is 0, there is no change. Thus, the plan for plotting our lines is outlined. All the lines pass through 0-0. All lines crossing .5 factor will have half values at that point.

To proceed, you would lay out the scale of final answers to cover the range. This can be placed at the bottom or top of the chart. It must be at right angles to the factor scale. The maximum chosen in Fig. 55*c* is 150 Gallons. This scale is the basis for plotting. Also, it provides points for plotting, inasmuch as it is on the line of unity factor change. Its points are locations of crossings of lines of corresponding volumes. These three conditions—base-line crossings, 50 per cent volume intersections, and 0-0 intercept—make for easy plotting of the concluding family. When located, the lines should be drawn in as broken lines. If the family for curves of dilution were dashed, these may be dotted.

Step 4. All that remains is to check the final chart and dress it up. Check it in several ways, being sure to use extreme examples. When you have proven it to be correct, then draw in one example to demonstrate its use. The one shown in Fig. 55*d* is as follows:

Information:	Initial gallons	150
	Initial Specific Gravity	1.4
	Final Specific Gravity	1.7

Question: How many gallons are evaporated?

$$X = 150 \times \frac{(1.7 - 1.4)}{(1.0 - 1.7)}$$

$$X = 150 \times \frac{.3}{-.7}$$

$$X = -\ 64.3 \text{ gal}$$

The minus sign means lost or evaporated. That would follow from the intent to concentrate the solution. And watch your step in the arithmetic. Keep in mind that Gallons added or evaporated are water, having Specific Gravity of 1.0 or unity.

USEFULNESS OF FAMILY METHOD

These and the examples in the previous chapter should give you enough of the graphics to apply this method. You should find a number of practical uses for it. It is a good method to have at your finger tips. It is easy to apply and therefore efficient. Its particular value lies in its rapid way for getting answers to large volume computations. You can build such charts often when you need quick solutions to current problems. The charts may never be required again. Because of these advantages, my recommendation is that you acquire a working skill with the family-of-curves method.

CHAPTER 16

NUMBERS PREFERRED

Lines have been the means used thus far for constructing our simple and complex diagrams. Now we want to introduce numbers to replace the lines. And while discussing numbers, there are some other details to be mentioned that are related. Consequently, we will interrupt the regular sequence in this chapter and the next to lay groundwork for those to follow. By way of starting off, let me emphasize the subject of numbers with a couple of incidents.

Ben wrote down ".5 minutes" as the time for the operator who asked what his standard was. Some time later, a different man asked how much time was allowed on the operation. This time my friend wrote it as ".50 minutes." In nothing flat, the first operator was at the desk vigorously complaining. He shouted that he had received only .5 minutes when his buddy had been allowed .50 minutes. Simple, I know, but such disturbances can be avoided.

Serious problems of industrial relations can stem from false notions of "accuracy" or amount. To extend the previous example a little further, think of a curve drawn on regular cross-section paper having 20 squares per inch. Suppose the standard time scale to have a spread of .10 minute for each major division of 20 squares. Then, one square equals .005 minute. Also unfortunately, one square is nearly 1/16 inch long. Now, 1/16 is a long distance on the slide rule that is repeatedly "read" or interpolated by the timestudy man. But if he is permitted or encouraged to interpolate curve readings as he is the slide rule, he can set up such easily obtained different standards as .005 and .005025 minute. Why does he do so when no good can come from it and complaints are more likely to be the result?

STANDARD THE SOURCE

Some may object, as one man did, "But the Accounting Department insists on five decimal places." This was brought on by the decimal hour plan. Why we should confuse 1,000 people in the shop with five decimal places for the pseudoconvenience of a half dozen in Accounting is beyond me. But that is another discussion.

So I recommended that if he felt he had to follow the system, he should use 0's in the meaningless decimal places. For example, he should express .53626 as .54000 decimal hours. In following this method, he would have avoided the problems being emphasized here. Besides, he would have helped the accountants save some money. To illustrate, if the standard were the multiplier in Pieces × Standard, there would be nine instead of twenty-two strokes on the comptometer. This detail seems important to me. In a much broader sense, I maintain that relatively the real problems of incentive are in the maintenance of the plan—not in the installation. The real cost and administrative work are in the upkeep—not the first cost. Many people disregard this fact. They know better. They know that their automobiles, their homes, their plant machines have to be maintained. But that is digressing from the subject.

The timestudy man initiates the clerical processes of incentive labor cost and payroll when he sets a standard. If he writes it with two digits or ten, the probabilities are that accounting will go on unquestioningly multiplying out exactly whatever figures he sets down. Therefore, this detail is important. Here we are discussing the *source* of the figures. In the Standards Departments, we set up what will be multiplied forever in extending earnings, assuming the plant and the incentive plan continue. Here is the point to control and to minimize one element of the clerical cost of the incentive plan. My recommendation is to hold the digits to two significant numbers. The maximum error does not exceed 4 per cent. Such an error would occur around the number 1 or unity. At 2, it would be halved, obviously. Of course, actually there can be no effect on earnings except in the isolated case where one operation on one size of product is the only one performed every day by an individual. The usual number of job changes will correct for this created error.

DEFINITE NUMBERS

The foregoing discussion about interpolation and increment error hinges on the form of the data. With a scale, the standard setter is very apt to try for an answer within a gnat's eyebrow. Different degrees of interpolation will cause inconsistencies. Interpolation most often occurs when curves are used. Tables are better for standard setting purposes. They have three main advantages.

The first advantage is that the standards are shown as *definite numbers.* In contrast, curves and nomographs have scales. Scales have to be interpreted before their readings can be set down as numbers. Reading the numbers directly from a table is faster and much less likely to result in error.

Second, numbers will usually include the decimal point. The positive recording of decimal points in a table reduces another possibility of error that exists with scales. When reading a scale, the standard setter must mentally create the number answer and then place the decimal point. This mental operation is necessary for 9 out of 10 applications when the scale has 10 divisions, or for 19 out of 20 with a 20-division scale. Again, the chances for error are less when standard times are set up in tables as actual numbers.

Third, but very important, is the advantage of simplicity. Most of us forget that some foremen and people on incentive probably got out of school before the subject of "graphs" was being taught. For that reason, we should assume that curves and nomographs are unknown to them, and therefore are "mysterious." As a matter of fact, many graduate engineers are unacquainted with nomographs. But numbers in table form are understood by nearly everyone. Consequently, numerical tables have the decided advantage when we are explaining how standards are set. For these reasons, my recommendation is that we convert our curves to the table or chart form.

CURVE INCREMENTS

To change curves to tables, we can use equations and compute the standards. Deriving the equation is easy when the curves are straight lines. It is more complicated when they are curved lines. Here you may refer to Chap. 11. In either case, we have to decide upon the interval spacing to use. As a rule, it seems that most timestudy men select uniform intervals of the dimension factors. They use increments like 10, 20, 30, 40, . . . , 100, or ¼, ½, ¾, 1, 1¼, . . . , 4. Such increments have changing percentages. For example, 10 to 20 is 100 per cent change, 20 to 30 is 50 per cent change, and 30 to 40 is 33⅓ per cent change. Of course, the same per cent change may not be present in the standard time equivalents. The dimensional factors are used here only to illustrate the point. By the same process of using uniform increment times, however, the same general variable would occur.

To overcome this variation, my approach is to use a constant per cent increment in Standard Time. Naturally, this produces a variable increment in dimensional factor. But Time is the important variable. It is the one that affects the job standard. And in my reasoning, a constant per cent of time increment is more correct than a constant amount of time increment. Using Standard Times like .04, .06, .08, .10, ..., .30 with a constant increment of .02, the percentage change is a variable similar to that previously illustrated for sizes. Reducing the amount of the increment would change the amount of actual percentages but not the fact of variable percentages. This is true, even when you compare the smallest increments of a curve drawn on 20-squares-to-the-inch paper. And since there must be intervals, it seems to me that the more logical choice lies with the constant per cent time increment.

UNIFORM INCREMENTS

This idea came to me a number of years ago when we had a chart that was too big to use. It had been built up on the basis of uniform increments in dimensions. To cut down a chart was a new problem. As an experiment, we set the slide rule at 105 to get 5 per cent increments and compared standards across the chart. The first few columns showed greater percentage spreads. As we went across the chart, however, alternate columns could be dropped out. Further on, two could be eliminated, then three, then four, and so on. Looking back, it was such a waste of time to build up all those standards. Some at the extreme right of the chart had less than one-half of 1 per cent change from the adjoining column.

From this experience you can see how not to build a chart, if you agree that a uniform percentage increment is correct. You can start with proper increments. These can be any reasonable per cent. My recommendation is 5 per cent for repetitive operations and 10 per cent for job shops. The increment is the difference between standards. But notice—in using 5 per cent, for instance, the spread is not 5 per cent error because the standard applied is for the dimension closest to the one that determines the change-over.

Let us use a few numbers to illustrate. Suppose we have the following portion of a chart. Decimal points have been omitted because the percentage differences are the same regardless.

Dimension..............	5	6	8	11	15	20
Standard Time..........	100	105	110	115	120	126

For Dimension 5, the standard of 100 is correct. The same is true for Dimension 6 at 105. But whole-number Dimensions are not usual. We will have many different Dimensions between 5 and 6. As an example, the standard for 5¼ would still be 100. For 5¾, it would be 105. At 5½, we can have our maximum per cent error. If the correct standard for 5½ should be 102.44, then the error of 2.44 is 2.44 per cent. Figured from 105, the error is 2.56 or 2.44 per cent. Thus the error is about half the spread between standards.

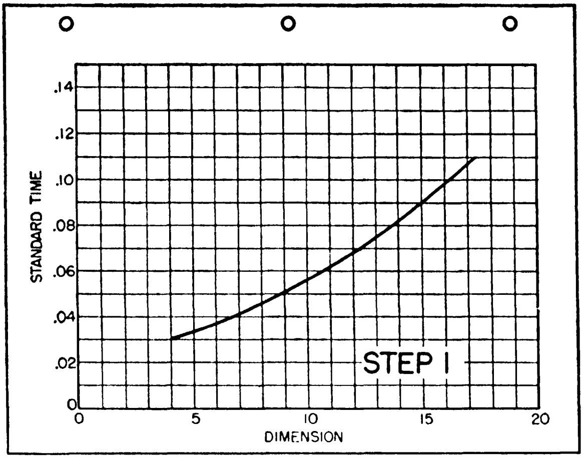
READING CURVES

Carrying this method to our everyday problems, it serves excellently for changing curves to tables. We begin, however, with the Time Standards instead of the Dimensions. In Fig. 56*a* we have a curve of a variable to be changed into table form.

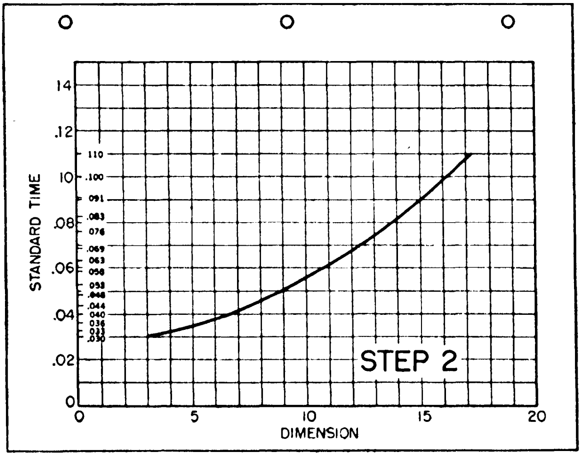
Step 1 is to lay out a per cent scale along the Time axis. The per cent increment used should fit the problem. To illustrate, we will use an approximate 10 per cent increment scale. The larger divisions will show up better in the reduced size of the example. These are laid out, starting with the least curve reading and progressing upward to the greatest standard (Fig. 56*b*).

Each graduation is then projected to the curve. This step shows in Fig. 56*c*. The intersections of the projections with the curve determine the locations of the corresponding Dimensions. By dropping verticals from these intersections, we can read directly the Dimensions that correspond exactly with the Standard Times (Fig. 56*d*). The results are summarized in chart form in Fig. 56*e*.

This graphical layout depicts one method. But you would not want to clutter up your data curve with all the lines. You would carry out the curve readings by a somewhat easier process. You



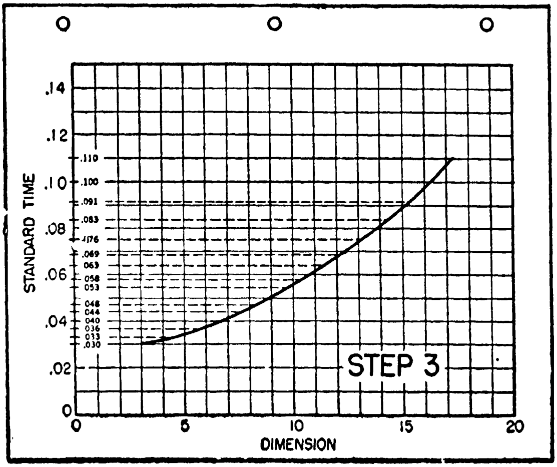
(*a*) A curve of a variable to be converted to definite numbers.



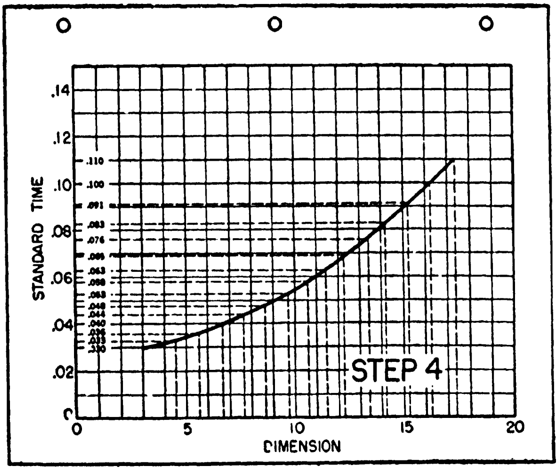
(*b*) A per cent scale is laid out on the time axis. In the example, an approximate 10 per cent scale is used.

FIG. 56.

could lay out the per cent scale on a separate piece of paper. Then, by moving the paper to the curve, you could get the same result. The paper edge is moved along successively for each mark of the per cent scale (Fig. 57). When it exactly touches the curve at one of the division marks, the edge of the paper will act as the verticals described in connection with Fig. 56*d*. Such scales could be saved for use later when similar curves were to be



(*c*) The per cent scale divisions are projected to the curve.



(*d*) The curve intersections are dropped to the Dimension scale to determine the dimensions that correspond with the starting per cent increment standards.

DIMENSIONS	STANDARD
3.0	.030
4.4	.033
5.6	.036
6.7	.040
7.6	.044
8.6	.048
9.7	.053
10.6	.058
11.4	.063
12.3	.069
13.4	.076
14.2	.083
15.2	.091
16.2	.100
17.3	.110

STEP 5

(*e*) **The exact standards are those laid out on the Time scale with their corresponding Dimensions.**

FIG. 56. (*Continued*)

converted to tables. Either of these methods can be used when there are several curves to be read.

CURVE-FAMILY READING

The translation of multiple curves to table form involves two considerations. One is the per cent increment between adjacent standards that we have been discussing. The other is the space factor. Both of these are illustrated in Fig. 58. The space factor will be developed more fully in our next chapter.

Step 1. Let's start with the family of curves shown in Fig. 58*a*.

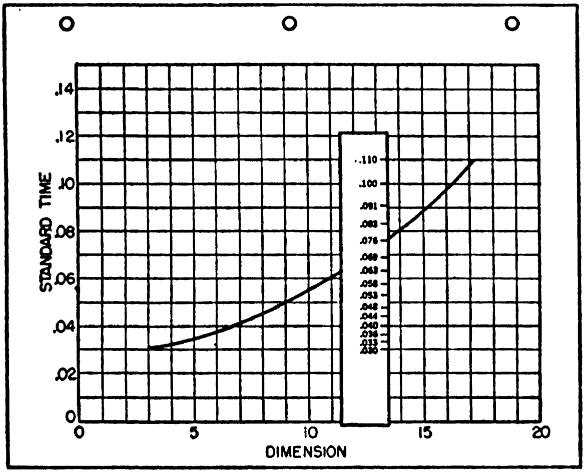


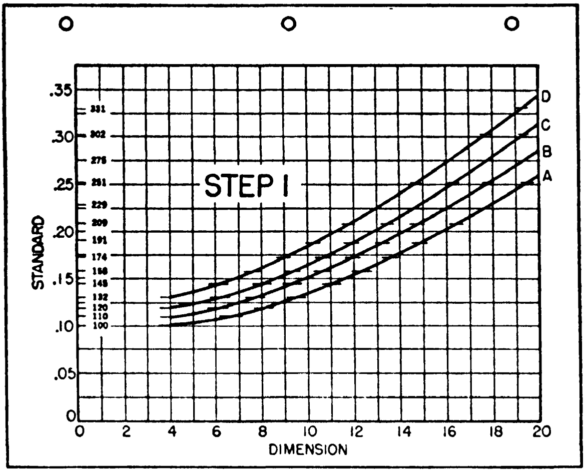
FIG. 57. Per cent increment scales may be used for curve reading instead of projections as in Fig. 56.

Step 2. These are changed to chart form by using uniform increments in Dimension (Fig. 58*b*). The changing per cent of difference in Standards is readily observed by comparing adjacent Standards in any column.

Step 3. To emphasize the use of uniform per cent increments, Fig. 58*c* was drawn up. This shows, also, a saving in space. Obviously, you can see that saving in space can be almost any amount. It depends upon the spread in the Dimension increments used in Step 2. But so, also, does the per cent increment in Standards. The closer the dimensional spread is held, the greater will be the space saving, in most instances.

CORRECT ELEMENTS

In the foregoing paragraphs, we have mentioned and illustrated the use of a constant per cent increment. The subject was touched upon also in Chap. 9 in attempting to answer the question, "How



(*a*) The family of curves is translated to table form using the same methods applied to single-curve reading.

CURVE DIMENSION	STANDARD			
	A	B	C	D
4	.10	.11	.12	.13
5	.10	.11	.13	.14
6	.11	.12	.13	.14
7	.11	.13	.14	.15
8	.12	.13	.15	.16
9	.13	.14	.16	.17
10	.14	.15	.17	.18
11	.15	.16	.18	.20
12	.16	.17	.19	.21
13	.17	.19	.20	.23
14	.18	.20	.22	.24
15	.19	.21	.23	.26
16	.20	.23	.25	.28
17	.22	.24	.26	.29
18	.23	.26	.28	.31
19	.25	.27	.30	.33

STEP 2

(*b*)

DIMENSION	CURVES			
	A	B	C	D
4.0 - 5.0	.10	.11	.12	.13
5.1 - 6.8	.11	.12	.13	.15
6.9 - 8.5	.12	13	.15	.16
8.6 - 9.8	.13	.15	.16	.17
9.9 - 11.5	.15	.16	.17	.19
11.6 - 12.5	.16	.17	19	.21
12.6 - 13.9	.17	.19	.21	.23
14.0 - 15.4	.19	.21	.23	.25
15.5 - 16.9	.21	.23	.25	.28
17.0 - 18.4	.23	.25	.275	.30
18.5 - 19.2	.25	.28	.30	.33

STEP 3

(*c*)

(*b*) Usually tables are made up from curves by starting with uniform increments in dimensions.

(*c*) Utilizing constant per cent increments will usually reduce the size of a chart. Compare with (*b*).

Fig. 58.

many curves in a family?" The constant per cent idea has a number of applications in chart making. Here we want to give a more complete discussion to the subject.

Before going on, however, it seems necessary to make clear one specific detail. The use of a constant per cent increment involves an error. The amount of the error is limited by the size of the per cent increment selected for use. These percentages are used in the charting of results that usually involve a grouping of elements. Such a grouping is quite different from a single element. This is brought up because we sometimes hear that it is all right to make an error in an element when the element is a small portion of a total. I want to make it clear that I believe the standard for each and every element should be determined as correctly as possible with the means available. In the standard data principle, each element is supposed to be correct within itself. It must stand alone. It will be applied in other parts of the shop. In such applications, it will constitute different percentages of various totals. The per cent will change as the operations are modified. They will change according to the type of operation, the type of job, and the methods change. Therefore, each element should be established as accurately as possible. That has nothing to do with the rounding out of numbers when elements are grouped. That is the difference we want to make clear at the outset.

PREFERRED NUMBERS

The ideas expressed in this chapter are related to a set of numbers similar to those frequently described as "preferred numbers." The numbers used here were specially devised. Initially, they were set up to overcome the problem of building up a chart with unnecessary columns and later erasing those. The purpose was to select a set of numbers that could be used directly in chart building. Later, these were modified to do other operations of multiplication and division. Subsequently, these numbers were worked up into special arrangements and I was granted a patent (2,295,497) covering their use. These specially arranged numbers are in logarithmic progression. That relationship makes them differ from selected numbers. Also, it makes them more useful in chart making where multiplication and division are to be used. These applications will be discussed in a later chapter.

CHOOSING THE PER CENT

At this point, we want to continue with the application of single sets of numbers. These may be in any progression suitable to your problem. To give you some perspective of the possibilities, Fig. 59 has been prepared to exhibit differing per cent increments. Under the usual circumstances, 5 per cent increments may be used for repetitive operations and 10 per cent for job shop standards. Greater increments than these can be used in instances where combinations are made. For example, when you add two sets of 10 per cent numbers together you reduce the per cent increment in the final results.

NOMINAL PER CENT SCALE EXAMPLES

2½	5	7½	10	12½	15	20
1 000	1 000	1000	1 000	100	100	100
1 023	1 047	1068	1096	112	117	126
1 047	1096	1141	1 202	126	136	159
1071	1148	1218	1318	141	159	200
1096	1 202	1301	1445	158	185	251
1122	1259	1389	1585	178	215	316
1148	1318	1484	1738	199	251	398
1175	1380	1585	1905	224	293	501
1202	1445	1693	2089	251	342	631
1230	1503	1808	2 291	282	398	794

FIG. 59. Comparisons of part scales of different per cent increment.

THE DIRECT METHOD

With a percentage increment scale determined upon, you can apply it directly in chart making. To bring out this advantage, we have worked out an example from Fig. 60*a*. Here we start with a common table made up directly from a family of curves. You will observe that such a table contains the same standard in several places. That is to be expected. But you will notice also that the per cent increment is greater at the top than at the bottom of the table. This condition exists even though certain Lengths have been omitted.

Now—compare the standards shown in the table with those having a constant per cent increment. Listing all the standards in the chart, we obtain the left-hand column of numbers on Fig. 60*b*. Such a list of numbers includes a wide range of per cent errors. For example, between the first and second numbers, 11 and 12, the increment is 9 per cent. At the other extreme, between 47 and 48, it is 2 per cent.

Listed alongside the original numbers are those from a preferred number list that have approximately a 10 per cent increment between numbers. The total count of numbers is 17 in all. These can be substituted for the 35 numbers shown in the left-hand list.

HANDLING STANDARDS

LENGTH	DIAMETER						
	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$
1	11	12	14	16	18	20	22
2	11	13	14	16	18	20	23
4	12	13	15	17	19	22	24
6	12	14	16	18	21	23	26
8	13	15	17	19	22	24	27
10	13	15	18	20	23	26	29
12	14	16	18	21	24	27	30
14	15	17	19	22	25	28	32
16	15	17	20	23	26	30	33
18	16	18	21	24	27	31	35
20	16	19	22	25	28	32	36
22	17	19	23	26	30	34	38
24	17	20	23	27	31	35	39
26	18	21	24	28	32	36	41
28	18	22	25	29	33	38	42
30	19	22	26	30	34	39	44
32	20	23	27	31	35	40	45
34	20	24	27	32	36	41	47
36	21	24	28	33	38	42	48

STEP I

HANDLING STANDARDS

DIFFERENT ONES IN CHART	TEN PER CENT STEPS
11	11
12	12
13	13
14	
15	15
16	16
17	17
18	
19	19
20	
21	21
22	
23	23
24	
25	25
26	
27	
28	28
29	
30	30
31	
32	
33	33
34	
35	
36	36
38	
39	
40	40
41	
42	
44	44
45	
47	
48	48

STEP 2

TOTAL NUMBER STANDARDS - 35 17

(*a*) (*b*)

Fig. 60.

(*a*) A chart made up from curves with some dimensions omitted.
(*b*) Comparison of the number of different standards recorded in (*b*) with the number needed when 10 per cent increment is used.

But notice—in order to obtain the left-hand list of numbers, all those in the table had to be written down in sequence. This was done after the table was prepared. This extra operation can be avoided. Starting with a list of preferred numbers, it is possible to write down only those to be used. The first number would be the lowest in the range. The others would be written in sequence and end with the highest in the range. If you will recall, this is the same approach that was used earlier in the chapter to "read" curves. Thus, we can use preferred numbers to set up tables directly or to translate curves, while attaining constant per cent increments in time standards.

With this explanation, we will conclude the chapter. Further developments will be explained in several chapters to follow. These will be given to methods for combining charts. Chapter 20 will describe, in more detail, the application of the constant per cent approach to charting. There are so many time- and space-saving advantages to be gained that it seems well worth your further study and application.

CHAPTER 17

SAVING SPACE

When numbers are subtituted for lines in charting, we have to consider the space factor. Space requirements are much more inflexible with numbers. For example, two digits are relatively constant in size. In contrast, the same two digits might be indicated on a scale line with almost any length.

Even so, if we look at the whole form instead of the lines, there appears to be a contradiction. This results from the fact that much space is lost between curves on line diagrams. To portray this detail, two examples have been made up. In Fig. 61, we have the single curve shown in both forms drawn proportionally. You can readily see that about one-tenth of the space is occupied by the two columns of figures. One column is needed for Dimensions. The other is used for the standard Times. Both are shown full length. But all this space may not be required. As you will recall from the discussion of preferred numbers, some lists shrink considerably when constant per cent increments are used.

Similar to the previous example, Fig. 62 also shows a substantial space saving when tables are used instead of curves. Less than 30 per cent as much is needed. And the same possiblities of reducing this amount exist with respect to the lengths of the columns.

NUMBER CHARTS

These two simple illustrations are only the beginning. They show only the first stage of multi-variable chart construction. They are necessary, of course, as the transitions from curves of variable elements to equivalent numbers.

Space consumed begins to multiply, however, as we combine more and more variables. Space should be utilized effectively. The efficiency of its use may determine whether or not the working data can be readily duplicated for economy in standard setting.

You easily recognize that complexities of the work being measured have a major influence on the size of its recordings. Of this, much is controlled by the ranges of the variables. We can do little about minimum size. Yet, we can do a great deal to reduce a size below some accepted minimum. To that end, I want to suggest several pointers that will be useful.

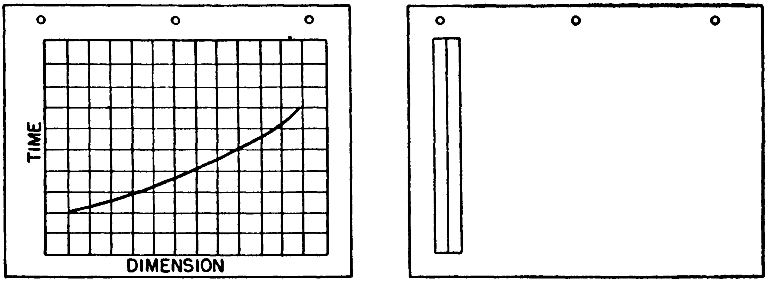


Fig. 61. Relative space required for a curve and its equivalent table is compared here in proportional drawings. A column of data may be no wider than three typewriter spaces.

WHY BOTHER?

Most important, of course, is the desire to conserve space. This may seem trite to you. "Why bother?" is a common question.

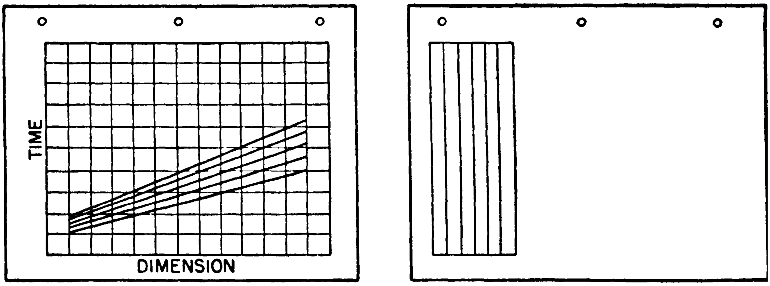


Fig. 62. Readings for each curve will require some part of one column. The columns are shown full length and four typewriter spaces wide relatively, but this amount of space may not be needed.

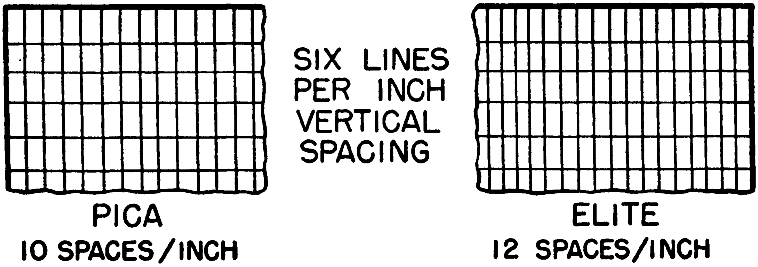
When that attitude is revealed, it can be entirely appropriate with respect to a current situation. For example, one section of the data is completed. It is typed for appearance and legibility. Then another section is finished and typed. Continuing, we wind up with a number of pages of typed data. Each set is spread out on its page to make it attractive-looking. But what is the result? Consolidation within a specified size like 8½ by 11 inches seems impossible. "It can't be done," is the first reaction. At this point desire becomes a necessary motive force.

Without desire and resolution, the working data remains spread out. Maybe there are two or three times as many pages as need be. Each has to be handled. Each adds to the enlargement of data books. Each extra page may be the cause of costly standard setting by reference and writing instead of the circling method on duplicated data. We have to want something earnestly enough to drive for it, if we are to attain our goals. That fundamental applies here in connection with this detail of space saving.

LAYOUT DEVICE

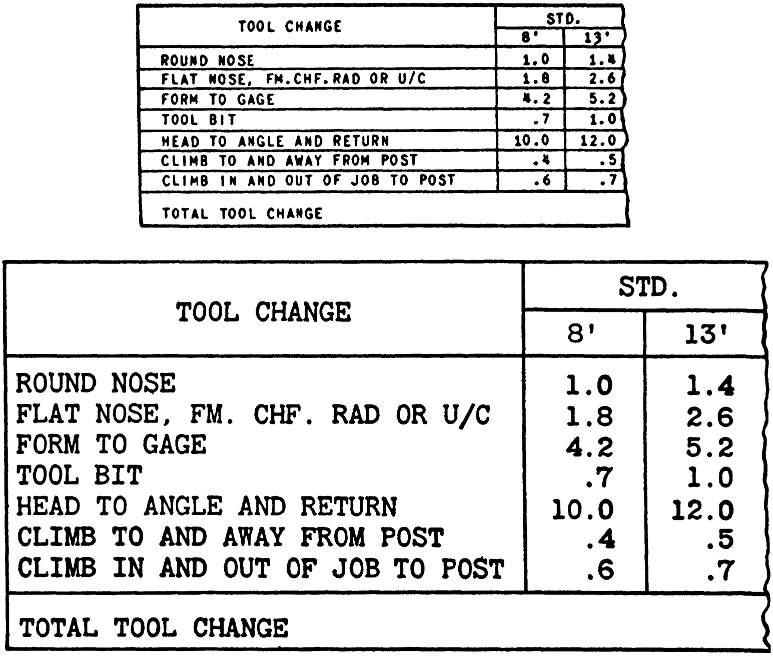
How many times has one of your stenographers said, "I can't get all that on one sheet"? Maybe she was right. Could you tell? Did you take, "No" for an answer? There is an easy way to get the facts. Besides, it will save much cost of retyping that is quite often wasted in the cut-and-try process. Get yourself some cross-section paper especially designed for layout to be typed. It should have 10 spaces per inch across the page if you use Pica type, and 12 if you use Elite. Spacing down the page is ordinarily six lines per inch. These types of papers may be found on the market, because some firms specializing in form design do use them.

Sample Typewriter Cross-section Design



This is only a detail, I know, but it may be a very useful one at times. It is nothing more than an application of the layout principle. We find out, in the shop, before we cut into a plate or a casting. We lay out in the Engineering Department, if we are smart, because it is cheaper to change our minds on paper. And if we use a gadget like this special cross-section paper, and find that the page is not big enough, we may decide to adopt printing. Setting the data in type may be too expensive. That all depends upon the repetition. But printing does afford another way to reduce space. Naturally, it makes for a nicer appearance.

Printing may be utilized in two ways to reduce space. One is the setting in type just mentioned. In type, you have a choice in sizes that enables you to condense a large amount of data into a small space. Relative proportions are shown on Fig. 63. There are compared two forms of the same chart, one printed and the other typed, the latter in 12-character-per-inch size.

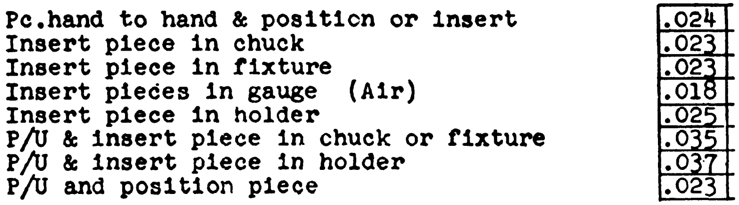


TOOL CHANGE	STD.	
	8'	13'
ROUND NOSE	1.0	1.4
FLAT NOSE, FM.CHF.RAD OR U/C	1.8	2.6
FORM TO GAGE	4.2	5.2
TOOL BIT	.7	1.0
HEAD TO ANGLE AND RETURN	10.0	12.0
CLIMB TO AND AWAY FROM POST	.4	.5
CLIMB IN AND OUT OF JOB TO POST	.6	.7
TOTAL TOOL CHANGE		

TOOL CHANGE	STD.	
	8'	13'
ROUND NOSE	1.0	1.4
FLAT NOSE, FM. CHF. RAD OR U/C	1.8	2.6
FORM TO GAGE	4.2	5.2
TOOL BIT	.7	1.0
HEAD TO ANGLE AND RETURN	10.0	12.0
CLIMB TO AND AWAY FROM POST	.4	.5
CLIMB IN AND OUT OF JOB TO POST	.6	.7
TOTAL TOOL CHANGE		

FIG. 63. A comparison of data reduced in printing with a typed chart in 12 per inch characters.

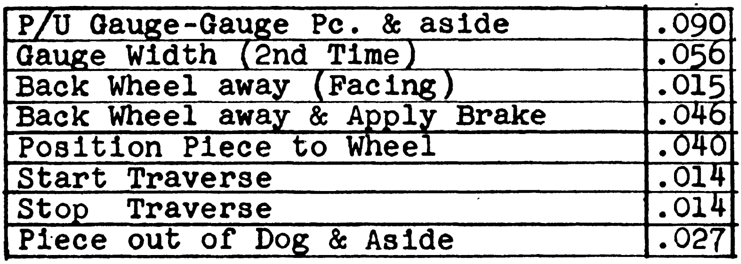
The other way to use printing to conserve space is through the medium of the offset process. Many folks use this process for everyday reproducing. If you are not familiar with it, what you need to know is that the process depends upon photographing the material to be printed. The next step is to create a "cut" by etching a sensitized zinc plate. The part important to our discussion is the photographic step. This can be used to reduce the size of the data when you need to do so. A reduction is limited only by the least size of standards and letters that can be read without errors of misinterpretation. Those shown in the accompanying illustration by no means approach that limit. Figure 64 compares a sample of reduced typing with one of full-size Pica typing, both duplicated by photo-offset printing. The one reduced in size has almost 14 characters per inch as compared with 10 in Pica typing. Notice, also, that in the photography the shrinkage takes place in both directions. The result is that in the reduced sample there are nearly eight lines per inch as contrasted with the standard of six lines.



Pc.hand to hand & position or insert	.024
Insert piece in chuck	.023
Insert piece in fixture	.023
Insert pieces in gauge (Air)	.018
Insert piece in holder	.025
P/U & insert piece in chuck or fixture	.035
P/U & insert piece in holder	.037
P/U and position piece	.023

(a)

(a) Data reduced by photo offset to approximately 14 characters per inch and 8 lines per inch.



P/U Gauge-Gauge Pc. & aside	.090
Gauge Width (2nd Time)	.056
Back Wheel away (Facing)	.015
Back Wheel away & Apply Brake	.046
Position Piece to Wheel	.040
Start Traverse	.014
Stop Traverse	.014
Piece out of Dog & Aside	.027

(b)

(b) Standard size Pica type affords 10 characters per inch and 6 lines per inch.

Fig. 64.

As a final suggestion, before deciding to print, you must consider the probable life of the form as it is designed. Remember that standard data is never completed. Also, I might add a personal comment: "If the data is reprinted in its present form, we have not made any progress in the meantime." Even with these limitations, there are instances where the printing of data sheets is advantageous.

GROUPING DATA

The difficulties of seemingly insufficient space may be overcome in other ways. One is through the grouping of data. Frequently, you can combine values to conserve space. In its simplest terms, grouping means the adding together of elements like Pick Up Piece and Piece Aside. Expanding on this, you can group more elements like those involved in a loading and unloading series on a lathe. For example

Pick Up Piece
Place in Centers
Tighten Tail Center
Loosen Tail Center
Remove from Centers
Piece Aside

You can extend this grouping still further. The practical limits depend upon likelihood of repetition. The larger the number of elements included, as a rule, the greater the number of different combinations. This is apparent to you. At the extreme, the combinations of all elements are the standards for the operation.

While we are on the subject of grouping, we should mention another form it may take. You might find occasion to place on one sheet the data from several related operations. One example is found in some foundries. Foundry data can be very complicated. It often is. At the same time, the number of operations is small in comparison with many other processes. So it happens that with a relatively few operations, you may be able to put all standard data on one sheet.

When related sets of data can be grouped on one sheet, there are other gains made beside that of space. Two are worth mentioning. The first is the repeated use of dimensional information and similar job specifications. Such details, necessary in whole or part for setting other standards, are already recorded on the work sheet for the first standard set. Consequently, you save either one or more copyings or calculations of these basic details.

Second, you eliminate extra handlings of the job and the extra mental setups of getting acquainted with it. It is so much easier when one timestudy man can set all the standards for the job in one processing. To use another example, he knows how many inches are involved on a seam, if he is setting standards for Fit and Tack, Weld, Chip, and Grind. Certainly, you cannot group together many types of data. When you do, you lose the advantages of specialization. Nevertheless, there are these savings to be made in specific cases. Be on the lookout for them.

EFFICIENT WORK SHEETS

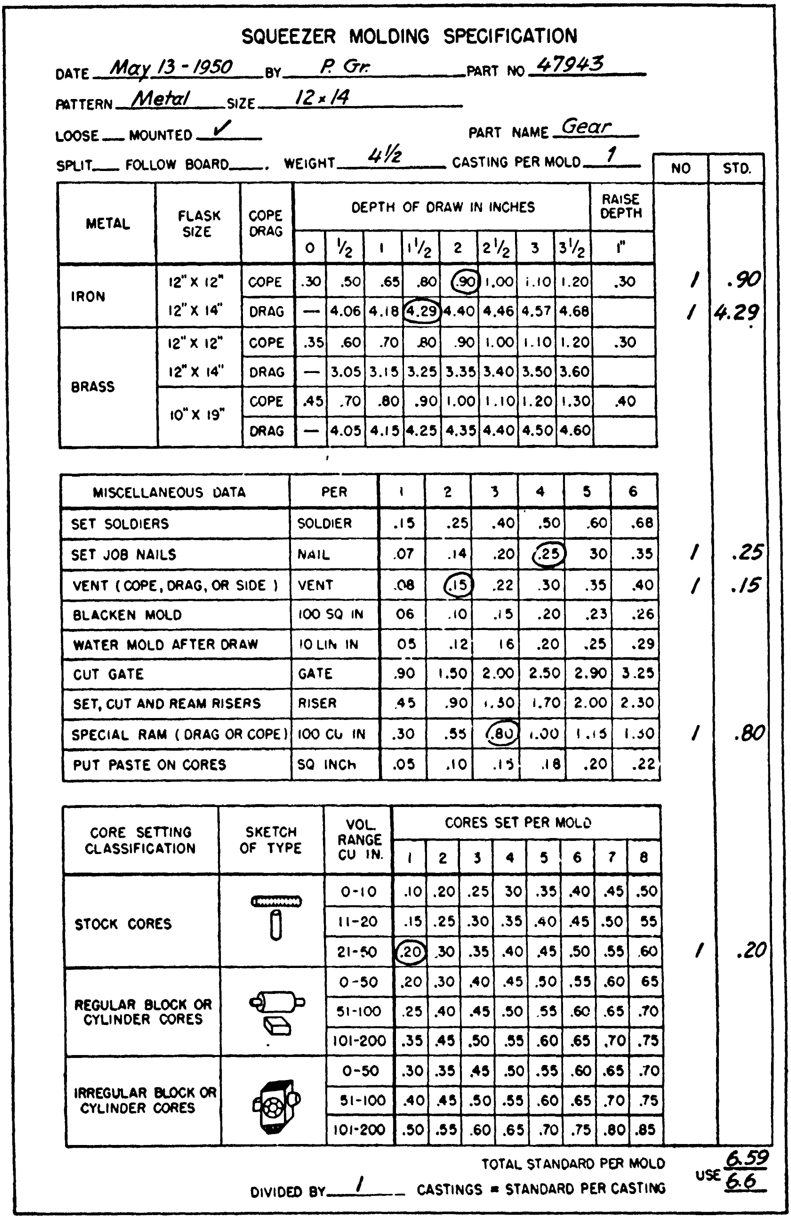
The space factor may appear to you to be unimportant. Often it is. But as the standard setting becomes more complicated, its importance grows. As the number and ranges of the variable elements increase, the space required to record them expands greatly. This works against the ideal arrangement of having all the data on one page.

An efficient data sheet, according to my experience, is one similar to Fig. 65, originally designed by John P. Bernard. All the element standards are recorded on one side of an 8½- by 11-inch page. This sheet is duplicated like any form. One sheet is used for each standard to be set. The "form" is "filled out" by inserting the job specifications at the top. Then each of the time factors is circled and its occurrence entered in the Number column. These are extended and added to compute the operation Standard. Notice that the method just described included no mention of copying element descriptions and standards from any other record. Also notice that the variable specifications for the elements are clearly identified by drawing the circles. For example, the cope Standard of .90 minute is obviously for a 12 by 12–14 box, for cast iron. These positive identifications were made by the circles.

The emphasis on clerical details here is necessary. Such little savings will add up to equal real economy in standard setting. This is important in job-shop and non-repetitive work measurement. It is a big factor too when management looks at the cost of the Standards Department. It is a vital detail in the cost of maintaining the incentive plan.

CLERICAL ERRORS

The copying of information from one place to another involves chances for errors. Decimal points may be misplaced. Figures may be transposed. Then, of course, errors will creep into extensions and additions. The important phase of clerical mistakes is their effect upon employee relations and confidence in the Standards Department. The shop people may be willing to believe the



SQUEEZER MOLDING SPECIFICATION

DATE *May 13 - 1950* BY *P. Gr.* PART NO *47943*

PATTERN *Metal* SIZE *12 × 14*

LOOSE ___ MOUNTED *✓* PART NAME *Gear*

SPLIT ___ FOLLOW BOARD ___. WEIGHT *4½* CASTING PER MOLD *1*

METAL	FLASK SIZE	COPE DRAG	DEPTH OF DRAW IN INCHES								RAISE DEPTH	NO	STD.
			0	½	1	1½	2	2½	3	3½	1"		
IRON	12" X 12"	COPE	.30	.50	.65	.80	.90	1.00	1.10	1.20	.30	*1*	*.90*
	12" X 14"	DRAG	—	4.06	4.18	4.29	4.40	4.46	4.57	4.68		*1*	*4.29*
BRASS	12" X 12"	COPE	.35	.60	.70	.80	.90	1.00	1.10	1.20	.30		
	12" X 14"	DRAG	—	3.05	3.15	3.25	3.35	3.40	3.50	3.60			
	10" X 19"	COPE	.45	.70	.80	.90	1.00	1.10	1.20	1.30	.40		
		DRAG	—	4.05	4.15	4.25	4.35	4.40	4.50	4.60			

MISCELLANEOUS DATA	PER	1	2	3	4	5	6	NO	STD.
SET SOLDIERS	SOLDIER	.15	.25	.40	.50	.60	.68		
SET JOB NAILS	NAIL	.07	.14	.20	.25	30	.35	*1*	*.25*
VENT (COPE, DRAG, OR SIDE)	VENT	.08	.15	.22	.30	.35	.40	*1*	*.15*
BLACKEN MOLD	100 SQ IN	06	.10	.15	.20	.23	.26		
WATER MOLD AFTER DRAW	10 LIN IN	05	.12	16	.20	.25	.29		
CUT GATE	GATE	.90	1.50	2.00	2.50	2.90	3.25		
SET, CUT AND REAM RISERS	RISER	.45	.90	1.30	1.70	2.00	2.30		
SPECIAL RAM (DRAG OR COPE)	100 CU IN	.30	.55	.80	1.00	1.15	1.30	*1*	*.80*
PUT PASTE ON CORES	SQ INCH	.05	.10	.15	.18	.20	.22		

CORE SETTING CLASSIFICATION	SKETCH OF TYPE	VOL. RANGE CU IN.	CORES SET PER MOLD								NO	STD.
			1	2	3	4	5	6	7	8		
STOCK CORES		0-10	.10	.20	.25	30	.35	.40	.45	.50		
		11-20	.15	.25	.30	.35	.40	.45	.50	55		
		21-50	.20	.30	.35	.40	.45	.50	.55	.60	*1*	*.20*
REGULAR BLOCK OR CYLINDER CORES		0-50	.20	.30	.40	.45	.50	.55	.60	65		
		51-100	.25	.40	.45	.50	.55	.60	.65	.70		
		101-200	.35	.45	.50	.55	.60	.65	.70	.75		
IRREGULAR BLOCK OR CYLINDER CORES		0-50	.30	.35	.45	.50	.55	.60	.65	.70		
		51-100	.40	.45	.50	.55	.60	.65	.70	.75		
		101-200	.50	.55	.60	.65	.70	.75	.80	.85		

TOTAL STANDARD PER MOLD *6.59*

DIVIDED BY *1* CASTINGS = STANDARD PER CASTING USE *6.6*

FIG. 65. An example of standard data arranged to reduce clerical work to a minimum.

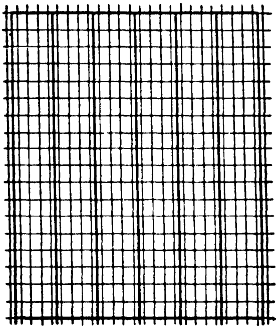
worst. There has been too much phony timestudy with subsequent "rate cutting." Just the same, an inconsistency is created by an error in arithmetic. And no matter what provisions there may be in a union contract that permit corrections of errors, it will be difficult to reestablish confidence. Even if there were no mistakes in arithmetic, it takes valuable timestudy time to make computations. For this reason, we should strive to reduce the number of calculations.

DIRECTION LAYOUT

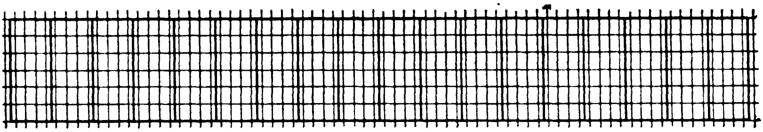
Having discussed some of the preliminary phases of space saving, we will go on with our subject as related to number charts. With combined charts, some additional problems present themselves. The charts become large and involved. As they expand, they tend to exceed the limits of the paper size. If you cannot get the chart on in one direction, you may turn the sheet. Therefore, one of the first steps is to do some planning of the layout. This may enable you to place the chart in the direction more convenient for everyday use.

To use an example, suppose you have six factors of Width and eighteen of Length. In combination, these will make an oblong table. The narrow side will be for the Width. The Length appears to be several times as great as the Width. But let's be more specific. We can calculate the dimensions using Pica typewriter spacing. Using two digits, one standard will occupy a space $\frac{2}{10}$ inch wide and $\frac{1}{6}$ inch high. If we add two spaces to the width for separation, the space width becomes $\frac{4}{10}$ inch. We can often use this basis even though sometimes it may be necessary to reduce the distance between numbers to one space in some charts.

Under the proposal, our standard takes up a space $\frac{4}{10}$ by $\frac{1}{6}$ inch. The total width becomes 2.4 inches (6 × .4), the total length 3.0 inches (18 × $\frac{1}{6}$). Normally, you would place the narrow dimension of the chart across the width of the sheet. Usually, this arrangement works out better. But since we are analyzing space requirements, we will calculate the width and length with directions reversed. Eighteen standards of $\frac{4}{10}$-inch width each need 7.2 inches of space width. Six rows of $\frac{1}{6}$ inch height take 1 inch of space height. (See Fig. 66.) So either of our two possible arrangements takes 7.2 square inches. The area will be the same either way the standards are placed because the area is the product of all four factors. This will be true even if we change the space measurements for one standard. But one placement requires a space of 2.4 by 3.0 inches. The other takes 1.0 by 7.2 inches. According to the problem, one is more convenient to use than the other. Therefore, if you are as desirous as I am to get all data on the work sheet, you will make determinations like these



(*a*) On Pica typewriter spacing paper, six factors across the width take up 2.4 inches. Eighteen factors placed vertically require 3 inches of page length.



(*b*) The same factors transposed require an elongated space of 7.2 by 1.0 inches.

Fig. 66.

in planning your layout. This phase of data consolidation might be broadly summarized as

> *Place the short-range variables across the sheet and the long-range ones vertically.*

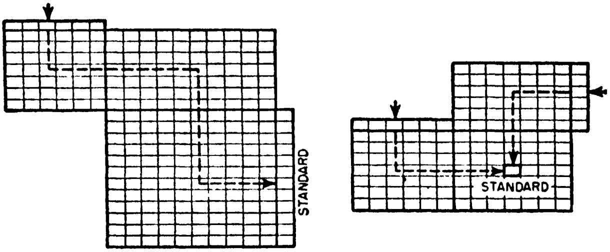
DIVIDING THE VARIABLES

In our next step, we come to another question, "What should we do when there are several variables?" In answering, let me say at the outset that sometimes you may not be able to make much of a choice. Sometimes the variables are complex, as in certain curve families. These involve at least two variables. They are easy to handle in the initial stage of combination. They are difficult to place in subsequent stages. So we might set down a rule that

> *Complex families of curves are more easily combined with other factors when placed first in sequence.*

If there is only one such family, it may be placed in either half of the groupings. If there are two, one may be used to start each half. This "half" idea has confused you, I know, but an explanation follows very shortly. Before leaving this detail, however, it is necessary to make another point.

Some problems involve the repetition of dimensional factors. To illustrate, you might have more than one part of a total standard dependent upon Length. In chart making, each use of Length as a dimension will take space. If these factors can be combined before charting, that is the obvious thing to do. But if they cannot be directly combined, then the next step is to try to utilize the one necessary space for showing the two or more factors. To attain this result may take considerable patience. If you persist, you can usually attain your objective and save considerable space. Methods used in overcoming a duplication are explained in Chaps. 19 and 20.



(*a*) Any number of variables may be placed in a sequence.

(*b*) Several variables may be divided into two groups of entering determinants

FIG. 67.

Now back to the halving of variables. With combinations, there are three or more variables. These may be charted all in one sequence or divided into two or more sequences. Two conventional ways of placing four variables are shown in Fig. 67. Here, in Fig. 67*a*, the four are arranged in sequence. This shows how four variables might be placed if there were seven or eight to be combined. In Fig. 67*b*, they are divided into two groups of two each. This exemplifies what I meant when I said earlier to halve the variables. To conclude, we can suggest that you try to

> *Divide the several variables into two groups to balance the space required.*

STUDY THE SPACING

The simple-line diagrams shown here may be confusing you because, as yet, nothing has been divulged about "how" to combine charts. My apologies. But I am trying to get all the discussion about space taken care of in one chapter. So if you will bear with me, we will get to the mechanics immediately thereafter.

Just a few more details should be mentioned. First is the study of space taken up when we have a multi-variable chart to lay out. Two considerations have been discussed. One dealt with the area occupied. The amount and arrangements were portrayed in Fig. 66. The other stressed the halving of the number of variables.

These two considerations are brought together in Fig. 68. The illustrations show but six of the many possible combinations. Several take up the same over-all box area. Each of the four factors used is indicated by the number written on the side it controls dimensionally. The extremes in arrangements are shown in (*a*) and (*f*). Diagram (*a*) occupies an area of 10.8 square inches calculated as Fig. 66 depicts. Somewhat larger areas are required for arrangements (*c*) and (*e*). In contrast, (*f*) requires only 10.7 square inches. This is computed as horizontal spaces $(7 + 10 + 1) \times .4$ multiplied by vertical spaces $(6 + 3) \times \frac{1}{6}$.

You cannot always interchange the variables as we have done in Fig. 68. You may be restricted by the mathematics. For instance, you may be required to add variables and then multiply by a factor. Also, as mentioned earlier, you may have complex variables that somewhat restrict the ease of placement. But when all variables are independent additions, you can elect to use that arrangement most convenient to your purposes. And in general, you will find that dividing the variables for two entries in determining the standard is the best plan.

CHARTING PAPER

The line diagrams in Fig. 68 are comparatively simple. They illustrate the problems of arrangement with only four variables.

Even so, you can see what is ahead if you want to build a multivariable chart with more than four variables.

For that reason, I want to mention a final detail here. It has to do with your layout paper. My suggestion is that you equip yourself with an appropriate kind. One feature of suitability is paper already ruled. This saves time. But there are many kinds of rulings. Most of what we see has ¼-inch squares. This will do, but it should be in the large sheet before it has been cut to pad size.

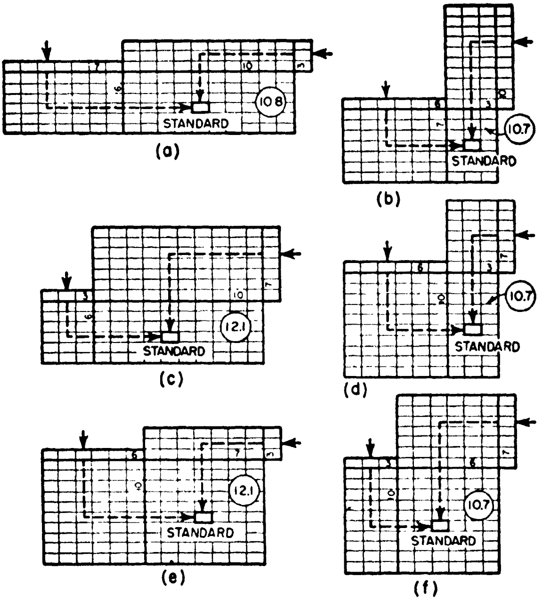


Fig. 68. Six arrangements of four variables. Many more can be made but these indicate the range in possibilities. The small numbers written on the lines indicate the number of factors in the direction shown. The figures in circles are the box areas.

Accidentally, I came across a much better ruling some years ago. It had oblong spacings, ¼ by ⅙ inch. This size is just right for the job of chart making. You can see how adaptable it is in the small sample shown in Fig. 69. So much for the ruling.

Also, consider the size of the paper. You want a big sheet to work with when the problem is complicated. You can start in one corner and have plenty of room to change your mind, without having to start over again. This feature is especially important until you become experienced in making complex types of charts. You can save yourself much copying by having plenty of room on the sheet. Of course, you can also save copying by cutting out the parts that suit you and pasting them on a new sheet.

PRELIMINARY ELEMENTS

The details of space considerations mentioned in this chapter are important in time saving. Handling, writing, and errors can be reduced, to the extent that standard data can be consolidated. The acme is attained when all can be placed on one side of the work sheet. This ideal arrangement is often produced by those who value such condensations. Often also, they have to do some real work to get the results they want. You have to be the judge of the proper balance between savings and cost. My suggestion is, however, that we need to give much more attention to satisfactorily explaining our work. This is aided greatly when all discussion can be centered on one sheet of paper.

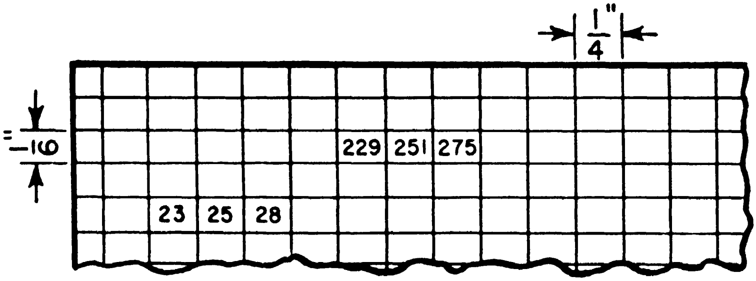


FIG. 69. Large sheets of blue-ruled cross-section paper may be obtained for chart making. The most convenient I have seen is a type with oblong spacings 1/4 by 1/6 inches. This sample is almost actual size.

Then, in the preceding chapter, we concentrated on numbers. These have definite advantages. Percentage numbers have certain special uses in addition to assisting in space saving, our topic in this chapter. Both these details are useful in chart making. They were dwelt upon, as an interlude, to lay essential groundwork for the discussions of multi-variable charting. Now we can go on with our prime subject in the next several chapters.

CHAPTER 18

CHARTING TIME DATA

Charts of standard data are made up from two general sets of conditions. One type is built up by calculating. The other results from the reduction of a curve or curves to numbers. Each of these will be discussed briefly, because much of our standard data is regularly used in table form. Also, as a rule, we start with this form of data, when combinations are planned to form multivariable charts.

QUANTITY CHARTING

Perhaps the simplest form of table is the one used for quantity standards. These are calculated. Two types are made. One is for multiples, the other is based on proration. A common example of proration is Gauge Piece—one in five, ten, and so on. This chart was computed by dividing the standard for Micrometer, .12 minute, by a series of quantities. In reverse, standards are often multiplied by different quantities. Both extensions and prorations should be set up in tabular form wherever it is practical. This is true especially when the tables can be reproduced on an 8½- by 11-inch work sheet. Such forms will save looking up, copying, and probable errors.

Gauge, 1 in every	1	2	5	10	25	50	100
Micrometer	.12	.06	.024	.012	.005	.002	.001

Tables that record divisions are more necessary than those for multiplications. More mistakes in arithmetic and decimal places show up when divisions are made as part of the standard setting process. Therefore, it is urged that you use tables like this example when dividing is a step in the computation.

We want to avoid mistakes. They are very expensive in direct cost and in the effects upon employee relations. I say "cost" because we hear about the mistakes on the "tight side." Beyond these, is the cost of the timestudy time used to make the calculations. And let me re-emphasize that we can use that time to greater advantages in extending incentive coverage.

For these reasons, then, we should make up charts that eliminate calculating. The cost per standard comes down in proportion as we reduce the number of calculations. This applies in any timestudy work. But with standard data, there is the *repetitive use* of the same calculations. With repetition in manufacturing, we find ways to improve methods. We should follow the same plan in standard setting. We should use more of the simple forms of tables designed to save computations similar to those shown on Fig. 70. These have been set up for quantities. The

Miscellaneous Data	Per	1	2	3	4	5	6
Set soldiers	Soldier	.15	.25	.40	.50	.60	.68
Set job nails	Nail	.07	.14	.20	.25	.30	.35
Vent (cope, drag, or side)	Vent	.08	.15	.22	.30	.35	.40
Blacken mold	100 sq in.	.06	.10	.15	.20	.23	.26
Water mold after draw	10 lin in.	.05	.12	.16	.20	.25	.29
Cut gate	Gate	.90	1.50	2.00	2.50	2.90	3.25
Set, cut, and ream risers	Riser	.45	.90	1.30	1.70	2.00	2.30
Special ram (drag or cope)	100 cu in.	.30	.55	.80	1.00	1.15	1.30
Put paste on cores	Sq in.	.05	.10	.15	.18	.20	.22

a. A section from the Squeezer Molding data shown in Chap. 17.

Wire for Plating		Loops Around			
		1	2	3	4
Twists	1	.073	.077	.080	.084
	2	.085	.089	.092	.096

b. A section from standard data for Wiring Parts for Plating.

T & L Screw by Hand	Number of Turns								
	¼	½	1	1½	2	2½	3	3½	4
Locate	.035	.040	.050	.060	.070	.080	.090	.100	.110
Fasten	.062	.068	.080	.092	.100	.116	.130	.140	.150

c. Data section arranged for Drill Press jig-screw handling.

FIG. 70.

necessary extensions were made once and checked. By this method, all future extensions are saved. Errors likely to occur in repeated calculations are eliminated. Another advantage is that any one of these standards is positively identified by drawing a circle around the controlling detail. This saves writing.

STEP VALUES

Aside from this discussion, your attention is called to another feature of a chart. You will notice, on the first line of the chart in Fig. 70*a*, that the Set Soldiers standards do not rise uniformly. For 1 we have .15, for 2 we have .25, and for 3 we have .40. This results from a "Get Two" of .05 minute and a "Set One" of .10 minute. The point involved is that such necessary differences can be set up in a table very conveniently. To correctly allow them another way would require references to two or more standards and calculations—certainly addition.

Many kinds of irregularities such as the one just described are easily provided for in chart form. One common example comes up in weight handling. When a wide range of weights is involved, there may be three variations. There are the one-man weights, the two-man weights, and those handled by crane. All can be incorporated in one chart, in the usual situation.

CHARTED CURVE DATA

The tables we make up more often are those derived from curves. Usually, these are set up by reading the curves at regular intervals. Often, the resulting standards have varying per cent increments as pointed out in Chap. 16. Several segments of such tables are shown on Fig. 71. These were taken from available data and reflect different choices of curve readings. Some of the increments in standards are more practical than others. Figure 71*a* has too much spread between adjacent standards. Too little is noticeable in Fig. 71*b*. This detail bears on the space occupied in charting. But in such tables, we have numbers in place of lines. This is a conversion necessary to our discussion here. Numbers lend themselves to ready combination. They can easily be added, subtracted, multiplied, and divided.

Tables like those illustrated are familiar to most of us. All of us have made and used them. We have often referred to similar ones in the handbooks. Most of these have one dimensional factor down the left side. Some have several columns spread to the right with a variable dimension at the top. One such table frequently seen in machine shops records diameters down the left side, Surface Speeds across the top, and RPM in the body of the table. Many such tables are constructed of timestudy data.

Two such very simple charts are shown in Fig. 72. Both of these record in numbers the standard times read from corresponding curves. As shown, they could easily be reproduced on a work data sheet and used by the circling method described in Chap. 17. Probably, the efficiency and accuracy would be almost equal to that of the form to be developed here. But that appearance results from the over-simplified tables selected for use in the explanation to follow.

SHEET METAL BRAKE BENDING

GAUGE	WIDTH AT BRAKELINE	PCS PER STROKE	AREA SQUARE INCHES						
			100	200	300	400	500	600	700
OVER 10 GAUGE TO $\frac{1}{4}$"	TO 10"	6	.25	.30	.35	.40	.45	.50	.55
	10$\frac{1}{4}$" TO 20"	4	.30	.35	.40	.45	.50	.55	.60
OVER $\frac{1}{4}$" TO $\frac{3}{8}$"	TO 10"	6	.42	.51	.60	.69	.78	.87	.96
	10$\frac{1}{4}$" TO 20"	4	.44	.53	.62	.71	.80	.89	.98

(*a*) Part of a chart for making a single bend with a Cincinnati brake.

BRAKE DRUM INSPECTION

INSPECT		DIAMETER IN INCHES										
		8	9	10	11	12	13	14	15	16	17	18
INDICATE AND PASS	RGH.	.25	.26	.27	.29	.31	.34	.36	.39	.41	.44	.47
	FIN.	.18	.19	.20	.21	.23	.25	.27	.29	.31	.33	.35
INDICATE AND REJECT	RGH.	.38	.39	.41	.44	.47	.51	.54	.59	.62	.66	.71
	FIN.	.27	.29	.30	.32	.35	.38	.41	.44	.47	.50	.53

(*b*) A chart for indicator inspection for out-of-roundness of automobile brake drums.

INSPECT AFTER PLATING

PICK UP INSPECT ASIDE	AREA INSPECTED SQUARE INCHES													
	50	60	70	80	90	100	160	220	280	350	400	500	550	700
STANDARD	.083	.088	.094	.099	.106	.110	.115	.119	.124	.129	.135	.143	.154	.162

(*c*) A section of a table of standards for visual inspection.

FIG. 71.

These charts have been simplified to the extent of introducing excessive increments. This was done to reduce size for more convenient reproduction. Correct charts for standard setting should not have more than 10 per cent increments between standards.

COMBINING STANDARDS

Assume for our example that the two tables in Fig. 72 are typical of those used every day for setting standard times for variable elements. In the usual procedure, standards would be selected from each table to conform with the operation dimensions. The partial standards would be recorded and added. As prepared, the tables cannot be combined to show a sum of the two standards as one figure. Yet a combination is desirable. It will save time and possible errors. Less time is required to write one total figure instead of two partial standards. When one total can be used, the time and effort of adding is eliminated together with the errors possible. Also, the errors that can occur when recording two standards instead of one are halved. These advantages multiply as the number of factors increases. Don't be misled by the words "two standards" used here because my explanation is being developed around simple charts.

DRILL TIME CHART		DIAMETER				
		$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$
DEPTH	$\frac{1}{8}$	.05	06	07	08	09
	$\frac{3}{16}$	06	.07	08	09	.11
	$\frac{1}{4}$	07	.08	09	.11	.13
	$\frac{5}{16}$	.08	09	.11	.13	15
	$\frac{3}{8}$	.09	.11	.13	.15	.18

HANDLING	
WT.	MIN
6	.08
8	.09
10	.10
12	.11
14	.12

FIG. 72. Two simplified charts of standard time data that cannot be combined in their present form.

As the tables are now arranged, however, we cannot add any of the standards for Piece Handling into the chart for Drilling standards. Before we can do so, we must change the form of the chart. Only two variables—Diameter and Depth—are provided for in the Drilling chart. Any chart that will combine the Handling with the Drilling standards must be laid out for three variables.

TURNING INSIDE OUT

Said another way, we can add together only the standard times of these two charts. But to add the time standards from the Piece

Handling chart to those for the Drilling, we must get the Drilling standards on the outside of that chart. This might be called "turning the chart inside out." Actually, the fundamental principle involved is to

> *Substitute standard times as one of the variables for one of the dimensional factors.*

Any "efficiency expert" would say, "Why set up a chart and then turn it inside out? Why not make it right the first time?" But that is second guessing. The Drilling chart is shown first as it is customarily made up in the Timestudy Department. The turning inside out only demonstrates how to get from what we have to what we want. Then, when we have seen that step of conversion and fully understand it, the unnecessary work can be eliminated in future chart making.

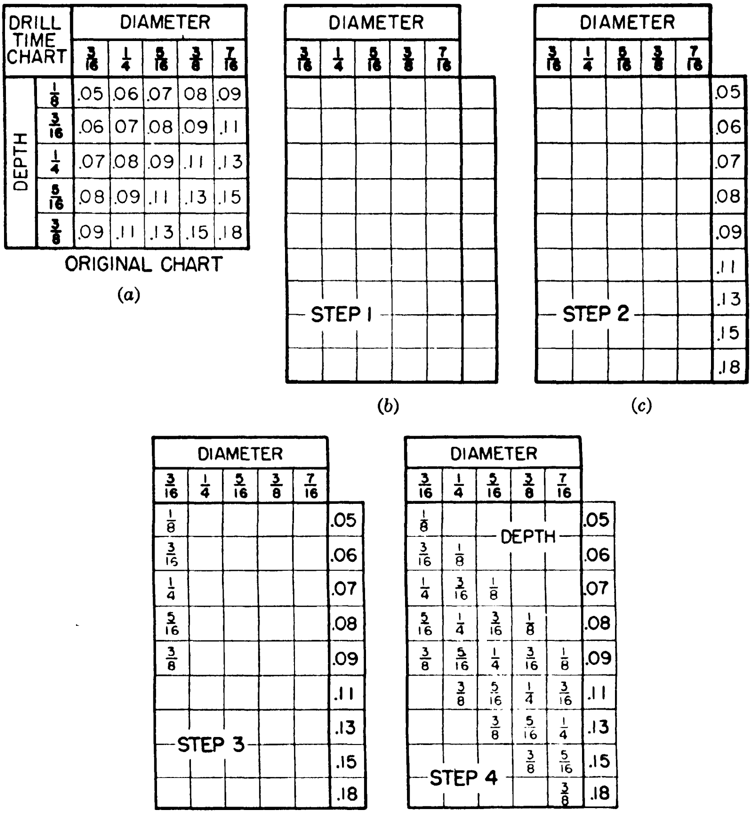
Grind Radius	Number of Teeth														
Up to 1/16	4	8	10	16	20	24	28	32	36	38	42	46	50	54	58
5/64–3/16	4	8	10	14	18	22	26	28	32	36	40	44	46	50	54
7/32–3/8	4	8	10	14	16	20	24	26	30	34	36	40	44	46	50
Standard.....	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

FIG. 73. Part of tool crib data for free-hand cutter grinding.

You may find that arranging charts in this inside-out form has certain advantages in some instances even when a combination is not planned. As an example, Fig. 73 shows a chart with 15 columns of numbers and standard times. To have drawn this chart with Number of Teeth across the top and Standards in the body, as in the usual manner, would have required 23 columns. Such a saving in space may be useful in attaining further consolidation. Therefore, consider this form of presentation as another tool in your working kit.

To proceed with the Drilling chart, Fig. 74 shows the steps in turning it inside out. Figure 74*a* is the original chart.

Step 1. We want to keep one of the dimensional factors just as it is. There are two to choose from. In many instances, one is a better choice than the other. In this example, let us keep the drill Diameter in the same location to reduce confusion. To begin, set up the caption Diameter at the top of the new chart. Then underneath, as column headings, write in the Diameters shown on the original chart (Fig. 74*b*).


DRILL TIME CHART
DIAMETER
DEPTH
ORIGINAL CHART
(*a*)
STEP 1
(*b*)
STEP 2
(*c*)
STEP 3
(*d*)
DEPTH
STEP 4
(*e*)

DRILL TIME CHART		DIAMETER 3/16	1/4	5/16	3/8	7/16
DEPTH	1/8	.05	.06	.07	.08	.09
	3/16	.06	.07	.08	.09	.11
	1/4	.07	.08	.09	.11	.13
	5/16	.08	.09	.11	.13	.15
	3/8	.09	.11	.13	.15	.18

DIAMETER 3/16	1/4	5/16	3/8	7/16	
1/8					.05
3/16	1/8				.06
1/4	3/16	1/8			.07
5/16	1/4	3/16	1/8		.08
3/8	5/16	1/4	3/16	1/8	.09
	3/8	5/16	1/4	3/16	.11
		3/8	5/16	1/4	.13
			3/8	5/16	.15
				3/8	.18

FIG. 74. (*a*) The original chart is so arranged that the standards cannot be factored. (*b*) Place one dimensional scale at the top of a cross-section sheet. (*c*) Write in a scale of standards to include the complete range. (*d*) Plot the other dimension scale values under the first dimensional scale and opposite their corresponding time standards. (*e*) Complete the plotting of the second dimensional scale. Now the starting chart is "turned inside out."

Step 2. Next we want to substitute the standard times for the Depth of hole. This is the step previously referred to as "turning the chart inside out." To begin this translation, we must list all the different standard times recorded. These are written in a vertical column similar to that used for Depth, beginning with the least time standard at the top. One detail is changed, however. The column of standard times is set up on the side of the chart most convenient for combining with other variables or standards to be included in the chart. The right-hand side is the location chosen in this example. The preferred location might be left side, top, or bottom in other solutions. Looking over the time standards, we find that the least one is .05 minute. That goes in the first square at the top of the column, on the first line below the title line of drill Diameters. Then, in sequence down the column, write all the standards. These are .05, .06, .07, .08, .11, .13, .15, and .18 (Fig. 74*c*).

At this point, it would be advisable to review the suggestion of substituting constant per cent increment numbers explained in Chap. 16. These standards used in illustration were much more conveniently arranged than you will usually find them. These standards are now placed as any dimension factor would be in a two-variable chart, except that we have written them on the right side instead of on the left. That change is only a detail bearing on a later stage.

Step 3. In constructing the usual chart, with one variable across the top and the other down the side, the next step is to fill in the body. In a regular chart, the body consists of standard times as made up in the chart labeled Original in Fig. 74*a*. But here, for the purpose of inversion, the standard times have been placed on the outside to the right. So now, we are to fill in the body with a dimension. In this case, having elected to retain Diameter at the top outside, the Depths will be plotted in the body of the chart.

Beginning with the column headed by the title for the least Diameter $\frac{3}{16}$, refer to the Original Chart to find the Depth corresponding with .05 Minute standard. That is $\frac{1}{8}$ Inch. Record $\frac{1}{8}$ Inch in the column under $\frac{3}{16}$-Inch Diameter and on the line opposite .05 Minute. Then refer to each Depth dimension in order considering only $\frac{3}{16}$-Inch Diameter. Plot each one in the $\frac{3}{16}$-Inch Diameter column opposite its corresponding standard time. The finished result should be like that shown in Fig. 74*d*.

Step 4. Continue the process introduced in Step 3 for all Depths to be used. Remember, however, to consider only one Diameter at a time. Complete the plotting of all Depths for one selected Diameter before taking up the next. After all are plotted, clearly label the area containing the plotted variable with its appropriate title. In this instance, it is entitled Depth. The end result will be a completely transposed chart like the diagram in Fig. 74*e*.

With our diagram completed, we have a chart that permits further combinations or mathematical computations. In gaining this end, we have lost some in the space factor. Our inverted chart takes up more area. This results from the over-simplified tables used as examples here. This disadvantage is not universally true. Earlier examples have shown how the opposite may be the result. You will find that, in general, the inverted chart will take up less space. The offsetting shrinkage will occur when you shift from the uniform dimensional standards ordinarily used in a table to the constant per cent standards selected for the layout of the outside column of your inverted chart. The more common occurrence of pronounced shrinkage was illustrated in Chap. 16. (See Step 2, Fig. 60.)

PLAN OF ENTRY

In the example just worked out, the column of standards was placed on the right-hand side of the proposed chart. This is a common location. We are in the habit of reading from left to right. You might say, then, that it is a good plan to work from left to right, in chart construction. This is our usual habit with commonplace tables. Notice that as a rule, also, we customarily lay out a table with its longer dimension running with the length of the paper. In publications, the long way of the page is usually in the vertical direction.

Therefore, you should plan your charts to conform with our reading habits and common practice. This will place the longer variable in the vertical direction, when conditions permit. More particularly, your final chart arrangement will often be controlled by the sub-chart used as the starting unit. As you will see later, this example in Fig. 74 determines the shape of the final chart. It was developed here as the starting unit. Consequently, the column of standards was placed in desired location on the right side in the vertical direction preliminary to the next step.

The end result of roughly half of a multi-variable is the outside column of standards. This is the longer line in a vertical direction, when it can be arranged to suit normal presentation methods. And this, in turn, establishes the direction of entry into the portion of chart built around it. Our example requires an entry from the top. We placed Diameter there at the outset, however, because we wanted our standards to be in a vertical column. It follows that our chart entry is at right angles to our column or row of standards when there are two variables. If another is added,

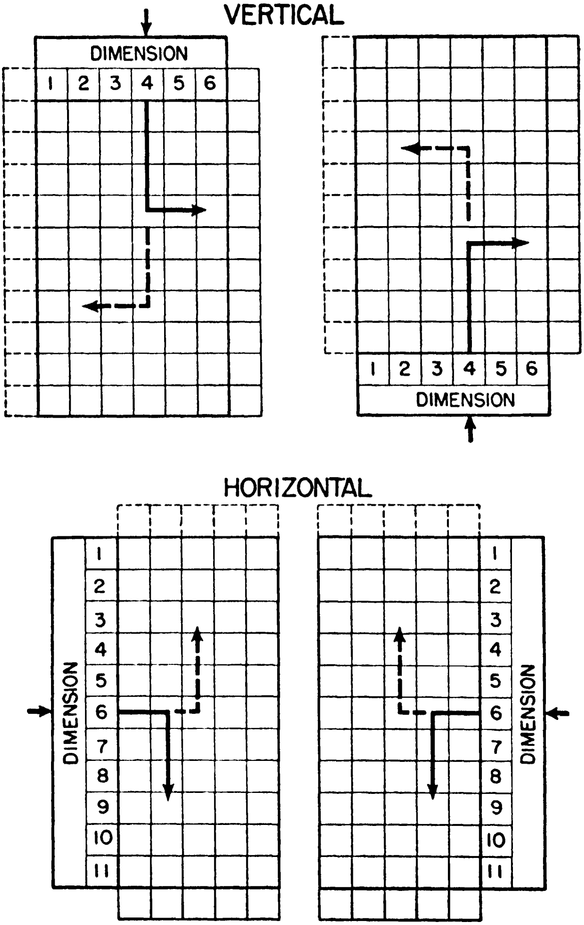
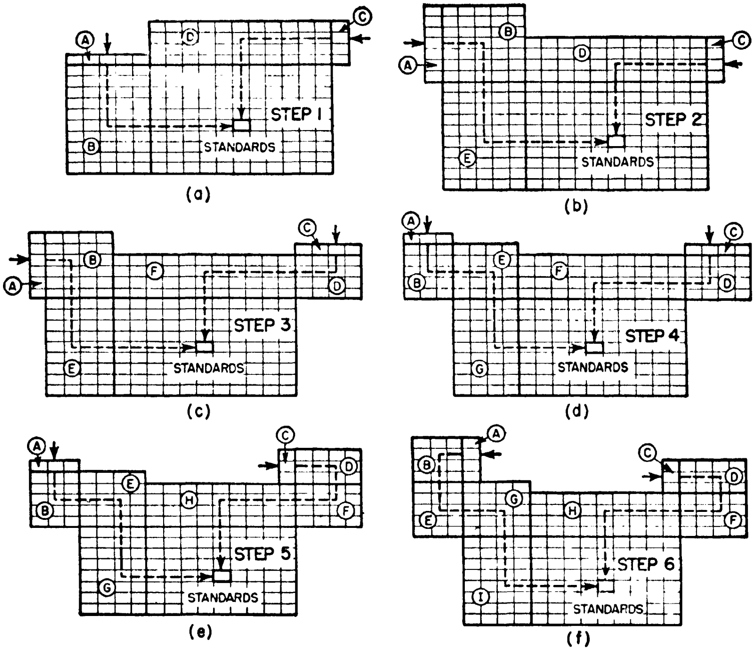


FIG. 75. Two variables may be arranged for vertical or horizontal entry. The right angle may be turned in either direction according to placement of this starting block in relation to the main body of the chart.

that introduces another 90-degree turn. The chart entry would then become a horizontal one if our example were built up to three variables. More of this later.

Limiting our discussion at this point to starting variables of only two, we have several chart entry possibilities. These should be understood before we go on to combine charts. The four indicated in Fig. 75 outline the choices. Vertical entry may be made from the top or the bottom. Horizontal entry can be arranged from either the left or the right side. Within the chart, the right angle may be turned in either of two directions as shown.



(a) (b) (c) (d) (e) (f)

FIG. 76. (*a*) A diagram of four variables—A, B, C, D. (*b*) Five variables with E added. (*c*) Six variables. F has been added. (*d*) Seven variables showing G as the new one. (*e*) Eight variables including H. (*f*) Nine variables are not the limit by any means. Our line diagrams simply conclude with the addition of I.

PROGRESSIVE ADDITIONS

Any of the line diagrams of chart entry may be used in a range of problem solutions. You may have either vertical or horizontal entry in either part of a multi-variable chart. The better one to use depends upon two details. First is the number of variables. Second is the way you divide the number between the two halves of the compound chart.

To illustrate probable arrangements, we have drawn Fig. 76. The outlines are hypothetical, of course. Nevertheless, they do show how you might plan a complete chart. This series is built up from Fig. 76*a* containing four variables to Fig. 76*f* including nine. As the series progresses, each added variable is joined alternately first with the left half and next with the right half. This carries out the suggestion of halving the variables.

These diagrams are misleading to some extent. They oversimplify the task of multi-variable charting. More especially, they deceive with respect to space expansion as the variables multiply. The word multiply was used deliberately. The space required by each added variable often is a multiplication of its individual space requirement by the space factors of those variables ahead of it in the progression. This accounts, in part, for the extended discussion previously of space saving. Also, this multiplying enlargement underlies the suggestion of halving the variables for double entry into a proposed chart.

Some of these general rules will become more evident as we progress. They are pointed out in advance so that you will know what to look for. These schematic diagrams should help you visualize the general plan of approach. Now let us see how to go about applying the fundamentals in making some actual multivariable charts.

CHAPTER 19

BUILDING MULTI-VARIABLE CHARTS

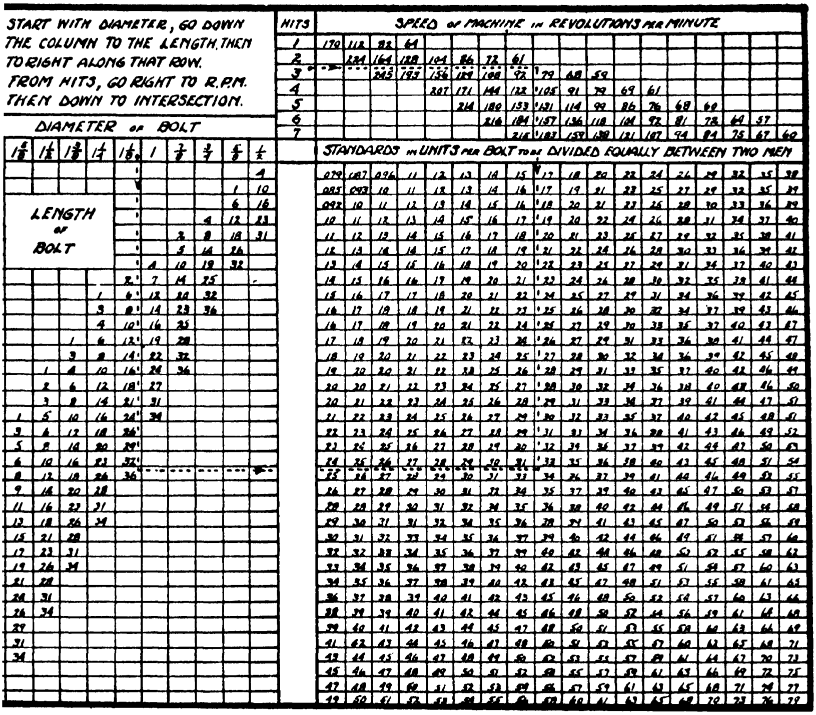
General principles are what they teach us in class. Each of us is supposed to apply those principles in our own work. The solution of problems still belongs to us. The best I can do here is to outline some simple applications. My hope is that they will be clear enough to create a general understanding of the wide range of possibilities open to you.

Unlimited numbers of variables and constants may be combined in chart form. We have seen several combinations set up in nomographs and families of curves. The same possibilities exist with the multi-variable chart. Some of the details have been discussed in the two previous chapters. Some examples have been used to demonstrate the application of the basic principles.

The basic idea depends upon the "turning inside out" of the usual two-variable chart. The idea is simple enough. Just the same, I can remember that my boss, Loyal Benedict, almost got gray hair back in 1924 when it took me three days to figure out one chart. My first multi-variable chart is not a complicated one, now that I look back on it. It contains only four variables, as shown in Fig. 77. But the "discovery" has been applied many times since. It has many uses. Some of the different ways of utilizing the general idea will be expanded on in this and the next chapters.

ARITHMETIC OPERATIONS

Essentially, the multi-variable chart is the same as the family of curves method. The difference lies in expressing results in number form. Numbers are used in place of the lines that show in the family of curve diagrams. If you will recall, the lines of the curves were drawn in between two scales placed at right angles to each other. In most of our examples, we started with a scale at the bottom and, by turning a 90-degree angle, we progressed from one variable to the next in succession in a clockwise direction around the cross-section paper. For simplicity, most of the diagrams were constructed with straight-line curves. The direction of movement could have been counterclockwise. It could have seesawed back and forth between only two scales so long as a right angle was turned for each change. Also, the straight-line curves could have been curved lines.



START WITH DIAMETER, GO DOWN THE COLUMN TO THE LENGTH, THEN TO RIGHT ALONG THAT ROW. FROM HITS, GO RIGHT TO R.P.M. THEN DOWN TO INTERSECTION.

DIAMETER OF BOLT
LENGTH OF BOLT
HITS
SPEED OF MACHINE IN REVOLUTIONS PER MINUTE
STANDARDS IN UNITS PER BOLT TO BE DIVIDED EQUALLY BETWEEN TWO MEN

FIG. 77. The first multi-variable chart set up by the author in July, 1924.

The direction of movement in the body of the chart is optional. Likewise, the scales may be placed in any convenient location and ascend in either direction. My personal preference is to so arrange the scales and directions that the final chart of standards has the least time value in the upper left-hand corner with the maximum in the lower right-hand corner.

In this general plan, our first step is to set up a column of standards on the outside of the chart so we can add, subtract, multiply or divide. We can take a square root, or square the numbers.

We can operate on a set of standards to perform any of the mathematical operations. Of course, the factors have to be applied correctly from the standpoint of mathematics. In many instances, however, the point where they are applied is optional. For example, in the nomograph chart made to calculate economical lot size, the .5 was applied at the end of the process. In this particular instance, it could have been applied at any of the stages from the first to the last. What has been discussed here applies to a scale of numbers or to the end results themselves. To be specific, you have seen a scale on the economical lot size chart converted to a square root of the answer obtained by the chart. Also previously, you saw pounds and inches substituted for the standard time equivalents.

Three different operations on the end result of one part of a chart are illustrated in Fig. 78. Here we have added a constant of .09 Minute in the first example, Fig. 78*a*. In the second, Fig. 78*b*, we have multiplied the end result by 2. The third, Fig. 78*c*, shows the equivalent of a multiplication attained by shifting the chart results to accomplish a per cent change in the answer determined. These and many other arithmetic calculations may be applied to the partial standards according to the factors required by the standard data. They may be applied to either or both halves of charted values as demanded by the conditions. This explanation is made at this point because these arithmetic calculations are often necessary intermediate steps to final combinations.

ADDING CHARTS

Most commonly, our element standards are combined by addition. Hence, it seems appropriate to continue our development of charting with such an example. Suppose we add some Handling standards to the Drilling chart we inverted in the previous chapter. This is shown in Fig. 79*a*.

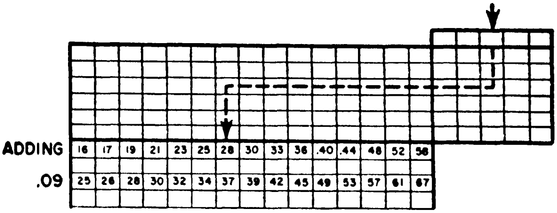
In 79*b*, we have a simple chart for Handling time arranged in its usual form. This must be re-arranged. We want the Handling chart to be horizontal rather than vertical. Its changed form is shown in Fig. 79*c*.

Reverting now to some of the layout ideas, our first step is to bring together our two sets of partial standards.

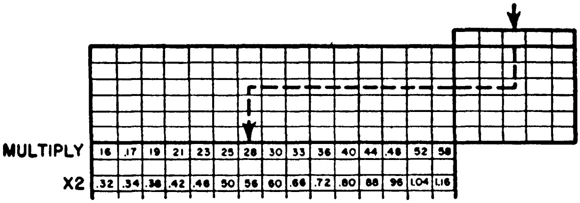
Step 1. The more common arrangement is shown in Fig. 80*a*. The chart for Handling should be placed at the top right of the

Drilling chart. In this layout, the two sets of standard times are ready for combining. With the Drilling time standards on the outside of the chart, we can add the Handling times.

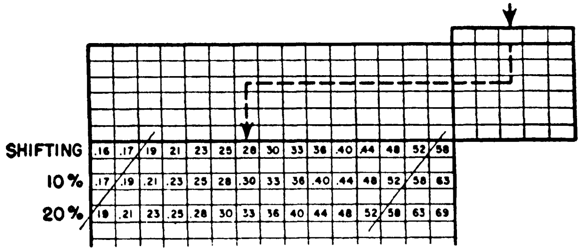
Step 2. All the standards for Drilling, from .05 to .18 Minute, apply regardless of Weight. These are shown in what now happens to be the center column of the chart. Therefore, we can combine any and all of these Drilling times with any and all of the Handling times. For example, when the Weight of a piece is 6 Pounds, the Handling standard is .08 Minute. We can add .08 for Handling to each of the Drilling standards. *Caution!* The sums must be set down in the column headed 6 Pounds. The first combination is .08 for Handling plus .05 for Drilling. All the combina-



(*a*) The combined results of a three-variable combination are increased by .09 minute.



(*b*) The total standards for three variables combined are multiplied by 2.



(*c*) The combined standards for three variables are increased by 10 per cent and 20 per cent as two examples.

Fig. 78.

tions for a 6-Pound piece show in the partially complete chart, Fig. 80*b*. Next, the .09 standard for Handling an 8-Pound piece is added to all the Drilling standards. These sums must be recorded in the column headed 8 Pounds.

When all the combinations are made, the chart is completed except for one detail. The construction figures should be removed, from the standpoint of a finished product. Consequently, in the final chart, Fig. 80*c*, the original Drilling and Handling standards

DIAMETER					
3/16	1/4	5/16	3/8	7/16	
1/8	DEPTH				.05
3/16	1/8				.06
1/4	3/16	1/8			.07
5/16	1/4	3/16	1/8		.08
3/8	5/16	1/4	3/16	1/8	.09
	3/8	5/16	1/4	3/16	.11
		3/8	5/16	1/4	.13
			3/8	5/16	.15
				3/8	.18

(*a*)

HANDLING	
WT.	MIN.
6	.08
8	.09
10	.10
12	.11
14	.12

(*b*)

WEIGHT				
6	8	10	12	14
.08	.09	.10	.11	.12

(*c*)

FIG. 79. (*a*) Inverted chart developed initially as Fig. 74*e*. (*b*) Chart of Handling Time in the usual form. (*c*) Rearrange the form of the third variable from vertical to horizontal.

are omitted. Only the combined standards show. The end result shown is usually copied from the make-up chart. The unnecessary construction figures can be left out in this step. But they will remain on the original. This should be filed away for reference when some future revision becomes necessary.

FOUR-VARIABLE CHART

From the foregoing, it can be seen that four or more variables can be combined. To work out an example with four variables, let us go on from where we started, in Fig. 80. We will use the Drilling chart and set up another to combine with it.

For the other two-variable chart, we will use one for Handling that is made up with Dimensions instead of Weight. This is done deliberately. It will bring out a way to get an end result

DIAMETER						WEIGHT				
						6	8	10	12	14
3/16	1/4	5/16	3/8	7/16		*.08*	*.09*	*.10*	*.11*	*.12*
1/8		DEPTH			*.05*					
3/16	1/8				*.06*					
1/4	3/16	1/8			*.07*					
5/16	1/4	3/16	1/8		*.08*					
3/8	5/16	1/4	3/16	1/8	*.09*					
	3/8	5/16	1/4	3/16	*.11*			STEP 1		
		3/8	5/16	1/4	*.13*					
			3/8	5/16	*.15*					
				3/8	*.18*					

(*a*) Place the third variable scale from Step 5 at the top of the proposed chart body.

DIAMETER						WEIGHT				
						6	8	10	12	14
3/16	1/4	5/16	3/8	7/16		*.08*	*.09*	*.10*	*.11*	*.12*
1/8		DEPTH			*.05*	.13				
3/16	1/8				*.06*	.14				
1/4	3/16	1/8			*.07*	.15				
5/16	1/4	3/16	1/8		*.08*	.16				
3/8	5/16	1/4	3/16	1/8	*.09*	.17				
	3/8	5/16	1/4	3/16	*.11*	.19				
		3/8	5/16	1/4	*.13*	.21			STEP 2	
			3/8	5/16	*.15*	.23				
				3/8	*.18*	.26				

(*b*) Add standards. Add one value for Weight to all values for drilling.

DIAMETER					WEIGHT				
3/16	1/4	5/16	3/8	7/16	6	8	10	12	14
1/8		DEPTH			.13	.14	.15	.16	.17
3/16	1/8				.14	.15	.16	.17	.18
1/4	3/16	1/8			.15	.16	.17	.18	.19
5/16	1/4	3/16	1/8		.16	.17	.18	.19	.20
3/8	5/16	1/4	3/16	1/8	.17	.18	.19	.20	.21
	3/8	5/16	1/4	3/16	.19	.20	.21	.22	.23
		3/8	5/16	1/4	.21	.22	.23	.24	.25
			3/8	5/16	.23	.24	.25	.26	.27
				3/8	.26	.27	.28	.29	.30

FINAL CHART

(*c*) Complete the chart and dress it up. Check the results against the original charts. Remove the construction standards. Draw in an example of procedure for using the chart.

Fig. 80.

like weight by means of a multi-variable chart built up from dimensions.

To work out the example, I used the Weights charted in Fig. 79*c*. These were set down as shown in Step 1, Fig. 81*a*, with the corresponding standards. Then the sizes of round bar stock were written in as one variable outside the chart (Step 2, Fig. 81*b*). The next move was to look up in a handbook the lengths of bars of the given Diameters that correspond with the Weights. These were plotted in the body of the chart (Steps 3 and 4, Figs. 81*c* and 81*d*).

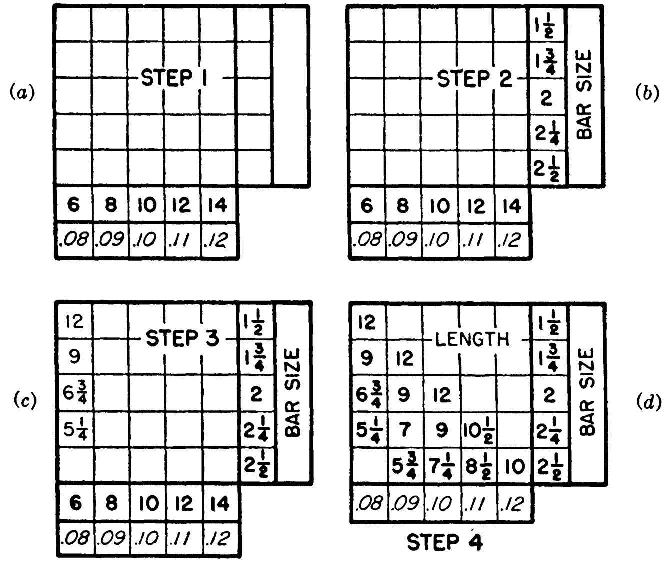
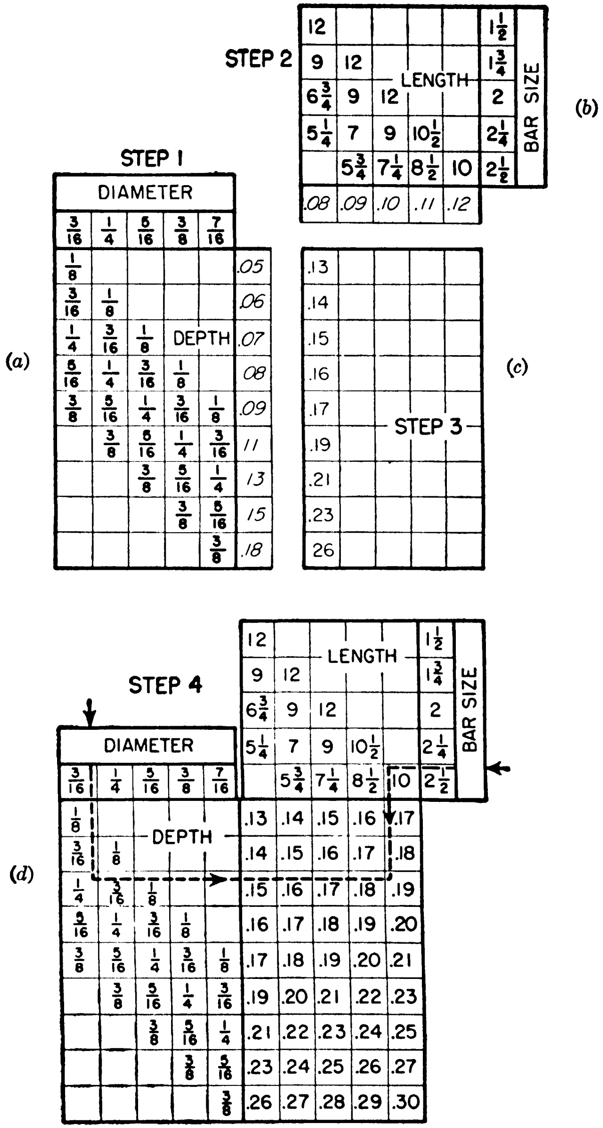


FIG. 81. (*a*) In place of pounds, we want direct-reading dimensions. So lay out a chart with pounds as construction figures. (*b*) Place one dimensional scale at right angles to start the two-variable chart. (*c*) Plot in the other dimensional scale after computing it. (*d*) Complete the second set of dimensional factors by computing or by looking up in tables.

Now we have a chart that selects the correct standard according to Weight without the necessity for computing the weight. This is an important variation. It is very useful. It should be substituted wherever calculations of weight or similar measures are made. More will be developed on the subject later.

Having completed the two-variable chart for Handling, we can make the combination.


STEP 2
LENGTH
BAR SIZE
(b)
STEP I
DIAMETER
DEPTH
(a)
STEP 3
(c)
STEP 4
DIAMETER
DEPTH
LENGTH
BAR SIZE
(d)

(b) STEP 2

LENGTH					BAR SIZE
12					1 1/2
9	12				1 3/4
6 3/4	9	12			2
5 1/4	7	9	10 1/2		2 1/4
	5 3/4	7 1/4	8 1/2	10	2 1/2
.08	.09	.10	.11	.12	

(a) STEP I

DIAMETER					
3/16	1/4	5/16	3/8	7/16	
1/8					.05
3/16	1/8				.06
1/4	3/16	1/8	DEPTH		.07
5/16	1/4	3/16	1/8		.08
3/8	5/16	1/4	3/16	1/8	.09
	3/8	5/16	1/4	3/16	.11
		3/8	5/16	1/4	.13
			3/8	5/16	.15
				3/8	.18

(c) STEP 3

.13				
.14				
.15				
.16				
.17				
.19				
.21				
.23				
26				

(d) STEP 4

					LENGTH					BAR SIZE
					12					1 1/2
					9	12				1 3/4
					6 3/4	9	12			2
DIAMETER					5 1/4	7	9	10 1/2		2 1/4
3/16	1/4	5/16	3/8	7/16		5 3/4	7 1/4	8 1/2	10	2 1/2
1/8		DEPTH			.13	.14	.15	.16	.17	
3/16	1/8				.14	.15	.16	.17	.18	
1/4	3/16	1/8			.15	.16	.17	.18	.19	
5/16	1/4	3/16	1/8		.16	.17	.18	.19	.20	
3/8	5/16	1/4	3/16	1/8	.17	.18	.19	.20	.21	
	3/8	5/16	1/4	3/16	.19	.20	.21	.22	.23	
		3/8	5/16	1/4	.21	.22	.23	.24	.25	
			3/8	5/16	.23	.24	.25	.26	.27	
				3/8	.26	.27	.28	.29	.30	

FIG. 82. (*a*) Step 1. Set up the inverted chart for drilling. See Fig. 79. (*b*) Step 2. Locate the computed chart for Weight Handling. (*c*) Step 3. Add one Handling standard to all the standards for Drilling. (*d*) Step 4. Complete the body of the chart. Check the answers. Then remove the construction figures and draw in a road map.

Step 1. Let's start with the transposed Drilling chart from Fig. 79*a* and set it up on Fig. 82*a*.

Step 2. Next we place at the top the Handling chart completed in Step 4 of Fig. 81.

Step 3. Then we add together the standards as indicated in Fig. 82*c*.

Step 4. The final result is a chart of four variables, Fig. 82*d*.

The completed standards are the same as those in the "Final" chart, Fig. 80*c*. That is because we used the same basic standard data in both examples. This seemed desirable in order to create a carry-over from the simpler chart. Besides, the examples could be used for both three- and four-variable combinations.

DIMENSIONAL FACTORING

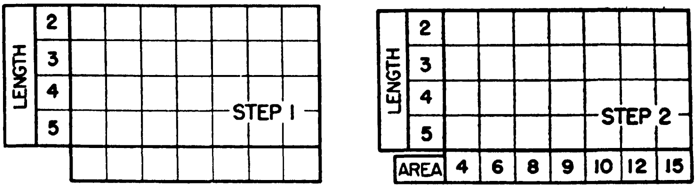
Before going on to multi-variable charts, we should say more about dimensional factoring. The subject was touched upon in the example just completed. There, we substituted Length and Diameter of round bar stock for Weight.

The example is a good one because Weight is rarely shown on drawings. Dimensions are what we find given in most cases. But Weight is what we frequently use to measure Handling time, when bulk is not an additional factor. Consequently, it becomes necessary either to compute Weight or to use a conversion method like the one demonstrated in Step 4 of Fig. 81. The latter is very much to be preferred in the typical shop-work measurement. It is faster and more errorproof.

To emphasize the point, we will set up another chart. This one will be used to compute another common measure—Volume. In its construction, we will obtain Area. Thus, the example will bring out the means for readily developing either of these frequently used measures. Remember, however, that the point is to use drawing dimensions as variables in charting. That practice is superior to using an end result like Area, Volume, or Weight. The example chosen is over-simplified. But illustrating the principle is all we are concerned with here.

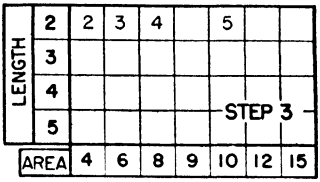
Step 1. To begin, consider the lengths involved in a problem. As examples, let us use 2, 3, 4, and 5. These are placed in vertical spaces as shown in Fig. 83.

Step 2. Next, the Areas involved are to be provided for. There are a number in the range. The least one is the product

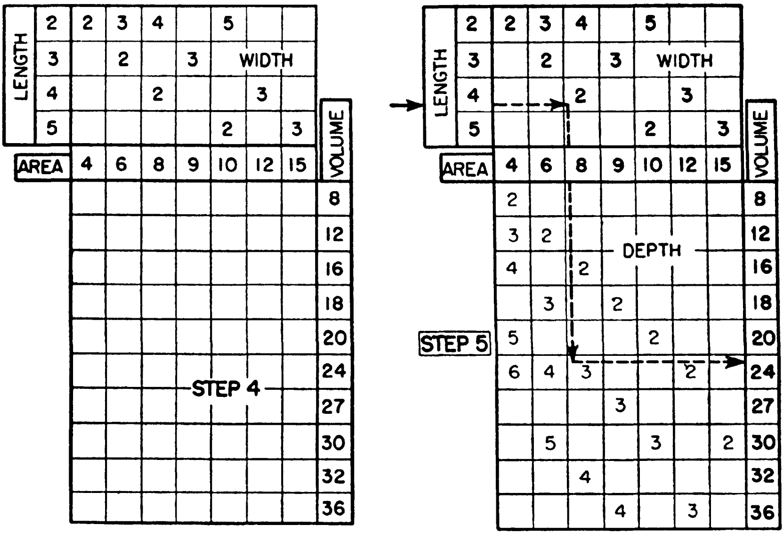


(*a*) Set up the Length variable to include the range of that dimension.

(*b*) Set up the Area starting with the least and ranging upward to include the greatest studied.



(*c*) Plot in the Width obtained by dividing the Area by the Length. Complete all Widths for one Length before going to the next Length.



(*d*) Complete the plotting of Width. Then set up the Volume starting with the least and ranging upward to include the greatest studied.

(*e*) Plot in the Depth. Find the Depth by dividing each Area in turn into all the Volume answers. Then the chart is complete.

Fig. 83.

of the shortest Length and narrowest Width. The greatest Area is the product of the extremes in Length and Width. The complete range of 4 to 15 is represented in Fig. 83*b* by the row of figures marked "Area."

Step. 3. With these two variables established, we are ready to plot in the Width. Starting with Length equals 2, we divide 2 into each of the Area figures. In this way, the Widths of 2, 3, 4, 5 are located in turn. The result is shown in Fig. 83*c*.

Step 4. Continuing with Length 3, and then 4, and finally 5, all the Width dimensions are plotted (Fig. 83*d*).

At this point, we have a completed chart for Area. It is a very simple example of chart construction that may be used for painting, and similar operations. Another application is in foundry molding where the element Strike Off often depends upon flask size—Length × Width.

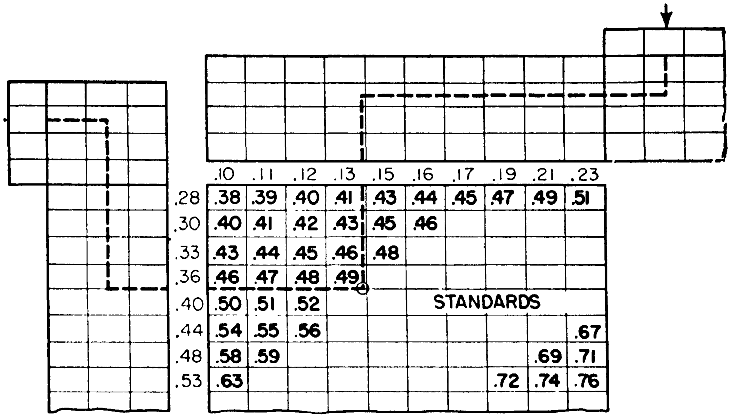
In molding and in other operations, it is necessary to know Volume also. So let's go on a step further. We can use this chart to give answers or time standards for both Area and Volume. To expand it, we proceed to set up the range for the Volume. Again, the range should include the least and greatest observed during timestudy. The volumes for our example are shown in Step 4, Fig. 83*d*, in the vertical column to the lower right of the chart.

Step. 5. The corresponding Depth or Thickness figures are obtained, as before, by dividing. Consider first Area equals 4. Divide 4 into each of the Volume figures and plot the results in their proper squares. When these computations are completed, the chart will be like Fig. 83*e*. Let's try it out. Take Length × Width × Depth as 4 × 2 × 3. The Volume answer is 24. It would be the same for 2 × 4 × 3 or 3 × 2 × 4. That is all right for straight arithmetic.

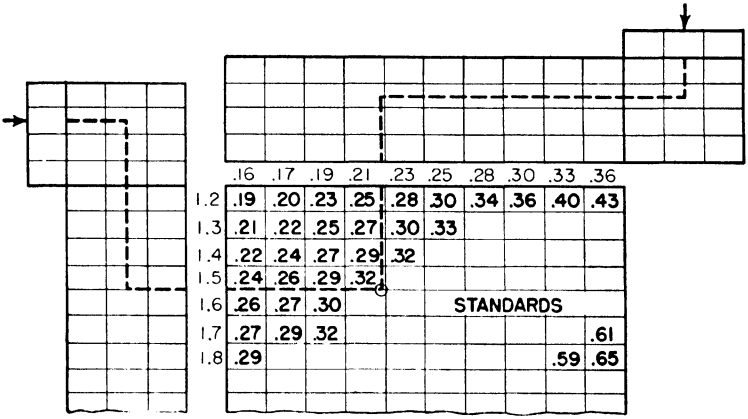
In timestudy work, however, our next step would be to substitute Standard Times for their equivalents of Area or Volume in tables like this one. That is the procedure recommended. It makes the chart one that is direct-reading and saves the time of referring to other charts. Also, such charts may be arranged to automatically take care of non-interchangeability of dimensions such as Length, Width, or Thickness as they may differently affect the standards.

SIX-VARIABLE EXAMPLES

Returning to time charting, two exhibits have been prepared to illustrate points previously made. These are shown on Fig. 84



(*a*) Outline of a six-variable chart showing two halves terminating with approximate 10 per cent scales.



(*b*) Three variables at the top conclude with a standard time scale. This is multiplied by factors that result from three variables combined in the left-hand portion of the chart.

FIG. 84.

Figure 84*a* outlines a six-variable chart. Each half concludes with a scale of standards predetermined from 10 per cent numbers. These are shown in the row immediately above the chart body and in the column next to it on the left. These are construction figures to be omitted in the final copy. These two sets of partial standards have been added, as in our Drilling chart.

But study the total standards. You will find that they are not in 10 per cent progression. The increment horizontally is 4 per cent, approximately. It is less than 10 per cent vertically. Obviously, this change results from the addition of numbers with uniform per cent increments. The per cent differences are lowered thereby. The reduction is different in the two directions because the two scales are of unlike magnitude.

In such instances, space savings could be made, if needed. Stated differently, if a constant per cent increment in final standards is acceptable to you, then scales to be added can be adjusted accordingly.

The other chart, in Fig. 84*b*, was drawn to show factoring. The construction scale across the top is in Standard Minutes. The vertical scale on the left is the one showing factors. The factors in this scale are multiplied by the standards in the top scale to produce the final standards shown in the body.

Such factors might be of any range. They might be divisors. It is apparent from this illustration how you may solve similar problems. They are the exception rather than the rule. But they do occur. This is one way to produce the results. It differs from methods used in Fig. 78. There, one non-variable factor was applied to the standards. Here, we have attempted to indicate how a series of multipliers might operate to affect the final standard.

ZERO FACTORS

Another detail we should not overlook is the case where a factor can be 0. You may have such a problem to solve. It occurs where you add standard time for part of an operation under certain conditions but omit it for others.

In such charts, you must insert a row of 0's for every factor that may be omitted. The row of 0's marks the location where you turn a right angle to avoid modifying the answer previously obtained. To emphasize this detail we have incorporated here a finished chart that was built to set total standards (Fig. 85).[1]

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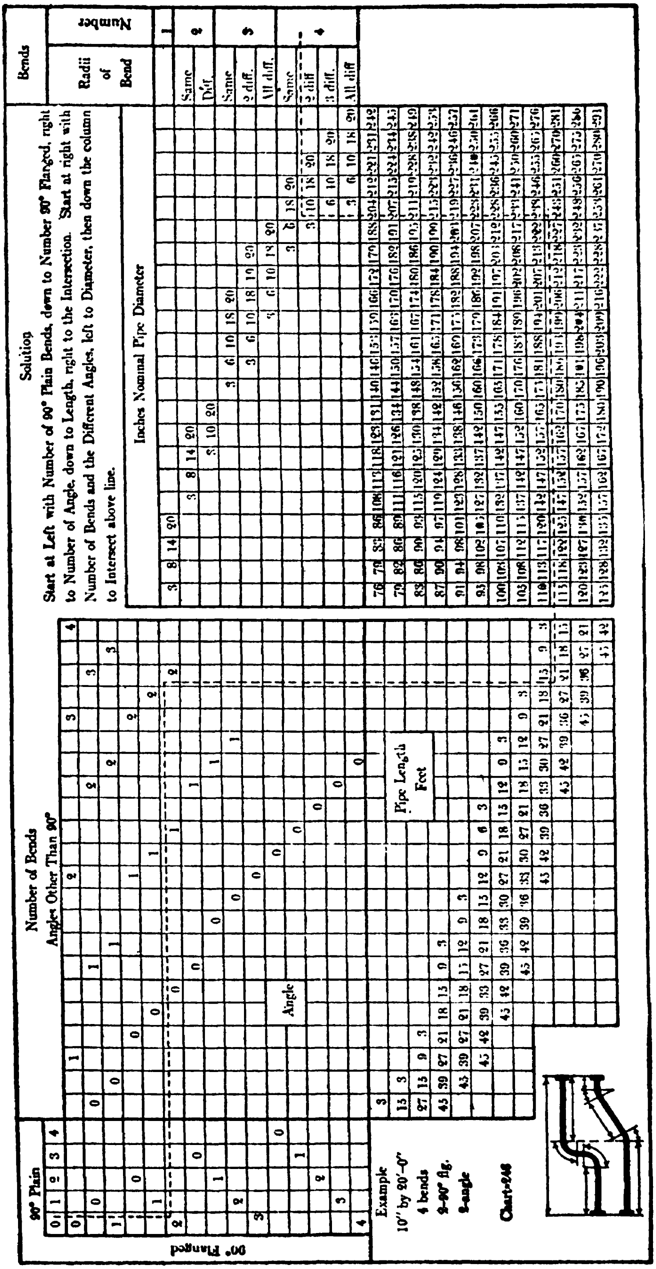
[1] Carroll, Phil, "Timestudy for Cost Control," 2d ed. p. 149, McGraw-Hill Book Company, Inc., New York, 1943.



Solution

Start at Left with Number of 90° Plain Bends, down to Number 90° Flanged, right to Number of Angle, down to Length, right to the Intersection. Start at right with Number of Bends and the Different Angles, left to Diameter, then down the column to Intersect above line.

Fig. 85. Multi-variable chart designed to furnish the total standard as one figure.

TYPE OF PATTERN							TYPE	
	X	R	IR				DRAG	BENCH
				VP	R	IR	COPE	
X	R	IR					DRAG	MACHINE
			VP	R	IR		COPE	

13	11	9	8	7	6	5		2.6
15	13	11	9	8	8	7		2.9
17	14	12	11	10	9	8		3.2
19	16	14	12	11	11	10		3.5
21	18	16	14	13	12	11		3.8
	20	17	15	14	13	12		4.1
	22	19	17	16	15	14		4.4

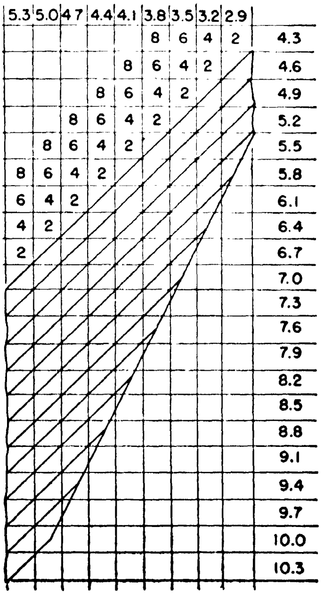
STEP I

(*a*) A section of standard times is laid out and volumes in hundreds of cubic inches are located according to type of mold.

TYPE OF PATTERN							TYPE	
	X	R	IR				DRAG	BENCH
				VP	R	IR	COPE	
X	R	IR					DRAG	MACHINE
			VP	R	IR		COPE	

13	11	9	8	7	6	5		2.6
15	13	11	9	8	8	7		2.9
17	14	12	11	10	9	8		3.2
19	16	14	12	11	11	10		3.5
21	18	16	14	13	12	11		3.8
	20	17	15	14	13	12		4.1
	22	19	17	16	15	14		4.4

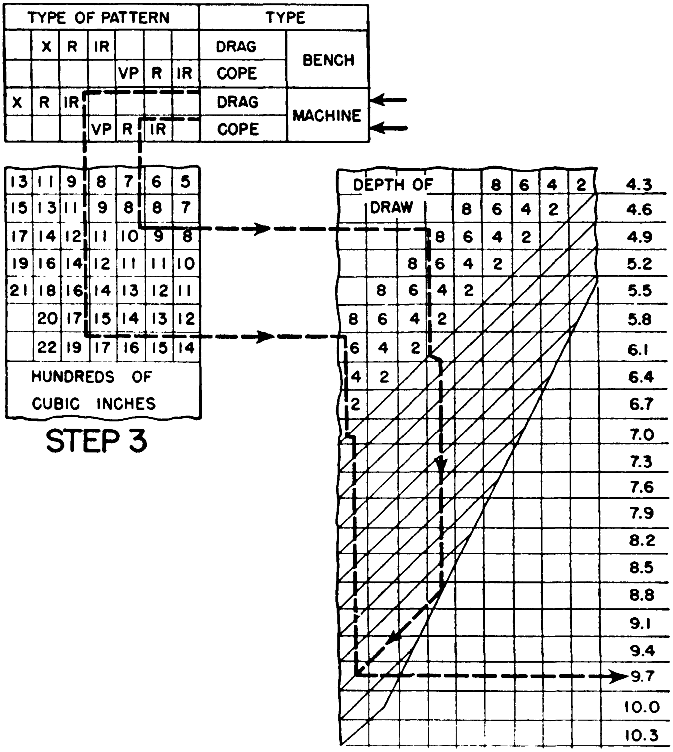
STEP 2



(*b*) A scale is located at right angles across the top so that Depth of Draw time can be added. Then a double scale is set up vertically for locating the diagonal line that combines.

Fig. 86.

You will observe 0's in the first three variables in the upper left-hand portion of the chart. These allow for the selection of any one, two, or three different types of bends according to the job specifications.



(c) Road maps show how two references are made from one set of charts and their results added.

FIG. 86. (*Continued*)

While we are on this subject, it needs to be pointed out that a chart should incorporate the opposite extreme. It should provide for maximums of all ranges. Including the full range is necessary so that the chart may solve any of the problems called for in its everyday applications.

DUPLICATED VARIABLES

Sometimes, the problem to be solved makes use of the same variables more than once. Such is the case in connection with the flask size in setting standards for molding operations. The duplicated variables present a problem in chart construction. We have the choice between repeating the variables in the chart or providing the means for double reference to the same variables. Such a problem is outlined in Fig. 86.

After many false starts, it was found that the two standards determined separately for the cope and drag could be added together before entering the main body of the chart. This was accomplished by means of a diagonal line reference that was laid out from a double scale. This example is an expansion of a section of the left-hand side of the chart for Squeezer Molding originally shown in Fig. 32 of "Timestudy for Cost Control"[1] and appears here as Fig. 87. The construction chart shown in Fig. 86 is modified somewhat from the original. However, the basic fundamentals involved are the same.

LABEL EACH VARIABLE

To avoid errors, it is necessary to properly identify each of the variables by name. Usually these labels can be placed in the blank triangles left by the plotting of the numbers. At times, there can be no mistakes because the numbers representing the variables are not interchangeable. Yet, this is not always the case. If numbers are interchanged, it is obvious that the resulting answers may be in error. For this reason, it is usually necessary to use the chart in the same manner it was constructed. Therefore, proper identification of each of the variables is very necessary.

The method for using the chart should be further defined by the insertion of a road map that shows both direction and sequence to apply in solving a problem.

Further detailed explanations may be placed in the blank spaces provided around the outside of the charts. Such available areas may be used for the recording of auxiliary charts and standard data. Examples of how these spaces can be used are shown on Fig. 87.

TWO FUNDAMENTALS

The charts shown in this chapter were designed to bring out two fundamentals. The first is the obvious one that we cannot combine "tulips and paving bricks." Only when we can modify

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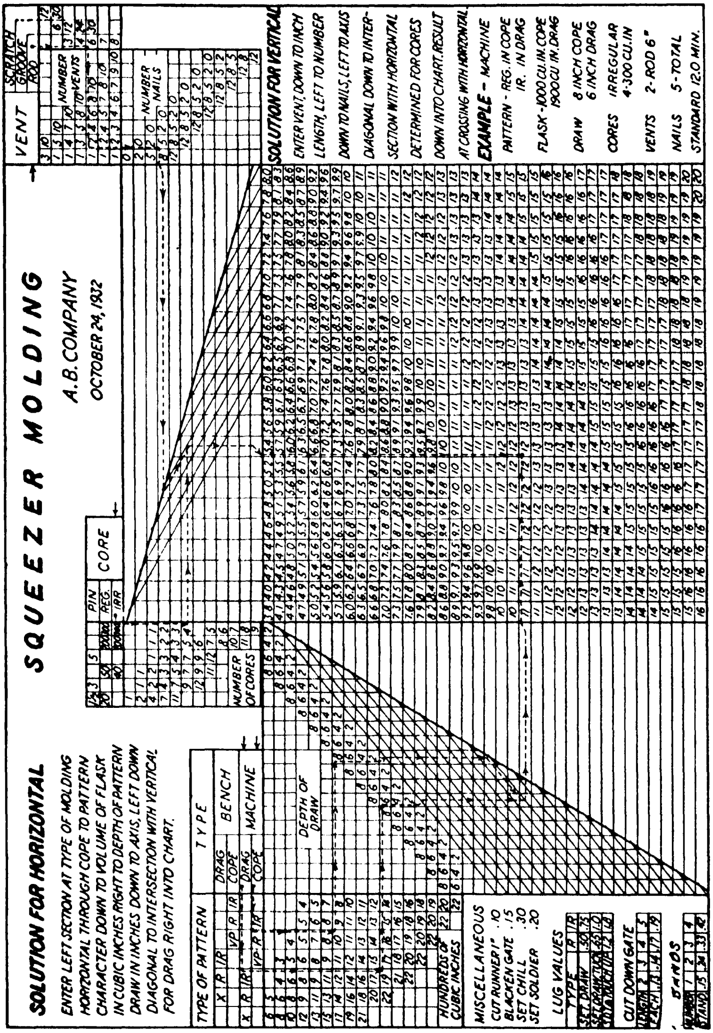
[1] Carroll, Phil, "Timestudy for Cost Control," 2d ed. p. 149, McGraw-Hill Book Company, Inc., New York, 1943.



SQUEEZER MOLDING

A.B. COMPANY

OCTOBER 24, 1932

SOLUTION FOR HORIZONTAL

ENTER LEFT SECTION AT TYPE OF MOLDING HORIZONTAL THROUGH COPE TO PATTERN CHARACTER DOWN TO VOLUME OF FLASK IN CUBIC INCHES RIGHT TO DEPTH OF PATTERN DRAW IN INCHES DOWN TO AXIS, LEFT DOWN DIAGONAL TO INTERSECTION WITH VERTICAL. FOR DRAG RIGHT INTO CHART.

SOLUTION FOR VERTICAL

ENTER VENT, DOWN TO INCH LENGTH, LEFT TO NUMBER DOWN TO NAILS, LEFT TO AXIS DIAGONAL DOWN TO INTERSECTION WITH HORIZONTAL DETERMINED FOR CORES DOWN INTO CHART. RESULT AT CROSSING WITH HORIZONTAL.

EXAMPLE - MACHINE

PATTERN - REG. IN COPE
IR. IN DRAG

FLASK - 1000 CU. IN. COPE
1900 CU IN. DRAG

DRAW 8 INCH COPE
6 INCH DRAG

CORES IRREGULAR
4-300 CU. IN

VENTS 2-ROD 6"

NAILS 5-TOTAL

STANDARD 12.0 MIN.

FIG. 87. Multi-variable chart designed to supply the total standard in the majority of usual operations.

the time scales are we able to expand time charts into those of multi-variable types.

The second was the "how" for turning a two-variable chart inside out. This step is the necessary beginning to combination with other variables. The time standards must be outside a chart as one of the variables before they can be modified.

Having set forth these fundamentals by means of simple examples, I hope that you can figure out how to apply them to expand upon the number of variables combined in one chart. The number is limitless. But of course, there are restrictions imposed by size and practicality. Problems of revision and of understanding are among the necessary considerations also. These restrictions, along with the costs to originate, have to be balanced against the savings attainable through less expensive standard setting and expanded coverage. Remember that better methods are what we are seeking as the means for extending sound work measurement.

CHAPTER 20

CONSTANT PER CENT CHARTS

Constant per cent increments have been described and illustrated in earlier chapters. At one point, it was stated that I had patented a calculating device based on a special logarithmic form of number progression. This particular gadget will be explained briefly here because it has certain common applications in chart making.

UNIT CARDS

Like many things, the patent grew out of a laborsaving device. The intent was to save first the writing and then the typing of numbers that repeated in many charts. Out of this came what I call a "unit card." These are printed in both 5 per cent and 10 per cent approximate increments. In this form, they can be used to perform any operations of multiplication and division.

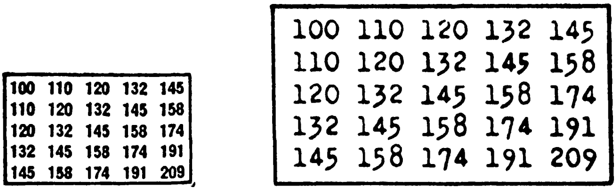
Certain space savings are made as shown in Fig. 88. Some of the difference in space results from separations in the printed form that are unlike those necessitated in typing. But observe, too, that printed numbers are easily read even though only about half size.

SHORT CUTS

The numbers in these chart sections are logarithmic in progression. Logarithmic scales are like those on our slide rules. They can be used to perform all types of multiplication and division. To illustrate, let's do a few problems with a section of such numbers.

The problems occur regularly in timestudy. For that reason, prepared numbers can be used to save the computing of tables of certain types. For instance, suppose you wanted the products of two series of numbers. Area figures are a common requirement. You will find that kind of answer on Fig. 89*a*. On this section of an approximate 5 per cent chart, select two figures. Take one in the left-hand vertical column, say 200. Assume another in the top row, perhaps 126. At the intersection of a horizontal line through 200 with a vertical through 126 is the product of 252. (See Fig. 89*b*.) This is approximate. The reason is that all these numbers have been rounded to three digits.

For another application, suppose you wanted a chart of standards multiplied by quantity. Assume the standard is .19 minute per square foot. Again, think of the left-hand column as the multiplier. Scan the right-hand column headed 191 as the product. If the least area you had to consider was 120 square feet, then part of your chart would look like Fig. 89*c*. As a matter of fact, you could simply make marks at the tops of the columns involved, hand the chart to your stenographer and ask her to copy those columns side by side.

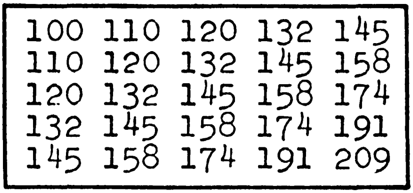


100	110	120	132	145
110	120	132	145	158
120	132	145	158	174
132	145	158	174	191
145	158	174	191	209

(a) PRINTED

100	110	120	132	145
110	120	132	145	158
120	132	145	158	174
132	145	158	174	191
145	158	174	191	209

(b) ELITE, 12/INCH



100	110	120	132	145
110	120	132	145	158
120	132	145	158	174
132	145	158	174	191
145	158	174	191	209

(c) PICA, 10/INCH

FIG. 88. Comparative samples of size of the same set of numbers reproduced.

MULTIPLE REFERENCES

Sometimes, you need several charts to solve one problem. These may be superimposed on each other, if there are appreciable savings to be made. This is an idea I first saw used by Bruce Wallace.

A greatly abbreviated chart that portrays the idea is shown in Fig. 90. This one has been arranged to perform two different types of computations, disregarding decimal places.

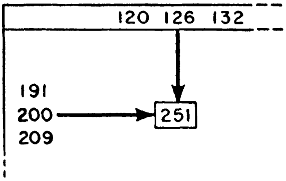
Multiply: $575 \times 158 \times 182 = 166$

Divide: $\dfrac{132 \times 316}{166} = 251$

Only five variables are set up at the entry at the top. These are placed upside down to show how pre-arranged numbers are used. They are the same numbers as appear both in the body of the chart and below it. But they must progress backward because of the nature of the problem. Normally, they would be lettered or typed in an upright position. Five are located for the bottom section. These are enough to indicate how you can arrange to utilize available portions of a chart for multiple references.

100	105	110	115	120	126	132	138	145	151	158	166	174	182	191
105	110	115	120	126	132	138	145	151	158	166	174	182	191	200
110	115	120	126	132	138	145	151	158	166	174	182	191	200	209
115	120	126	132	138	145	151	158	166	174	182	191	200	209	219
120	126	132	138	145	151	158	166	174	182	191	200	209	219	229
126	132	138	145	151	158	166	174	182	191	200	209	219	229	240
132	138	145	151	158	166	174	182	191	200	209	219	229	240	251
138	145	151	158	166	174	182	191	200	209	219	229	240	251	263
145	151	158	166	174	182	191	200	209	219	229	240	251	263	275
151	158	166	174	182	191	200	209	219	229	240	251	263	275	288
158	166	174	182	191	200	209	219	229	240	251	263	275	288	302
166	174	182	191	200	209	219	229	240	251	263	275	288	302	316
174	182	191	200	209	219	229	240	251	263	275	288	302	316	331
182	191	200	209	219	229	240	251	263	275	288	302	316	331	347
191	200	209	219	229	240	251	263	275	288	302	316	331	347	363
200	209	219	229	240	251	263	275	288	302	316	331	347	363	380
209	219	229	240	251	263	275	288	302	316	331	347	363	380	398
219	229	240	251	263	275	288	302	316	331	347	363	380	398	417
229	240	251	263	275	288	302	316	331	347	363	380	398	417	437
240	251	263	275	288	302	316	331	347	363	380	398	417	437	457

(*a*) Section of a unit card of approximate 5 per cent numbers.



(*b*) A line diagram to illustrate one use of (*a*). Products are found at the intersections of two number lines.

AREA	STANDARD
120	22.9
126	24.0
132	25.1
138	26.3
145	27.7

(*c*) Charts for quantity standards may be copied directly.

Fig. 89.

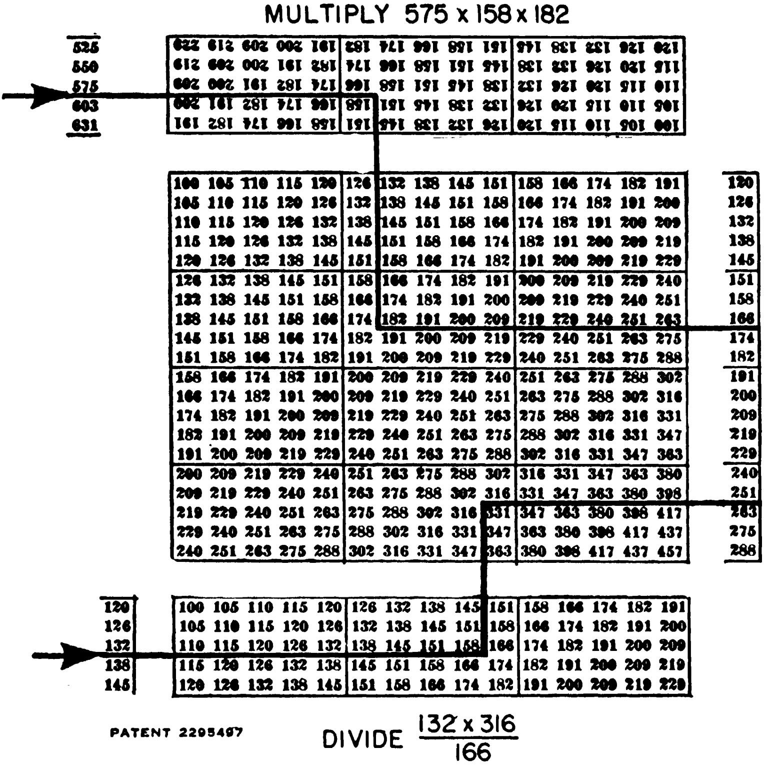


FIG. 90. Chart arranged to utilize portions of one chart body in two different solutions.

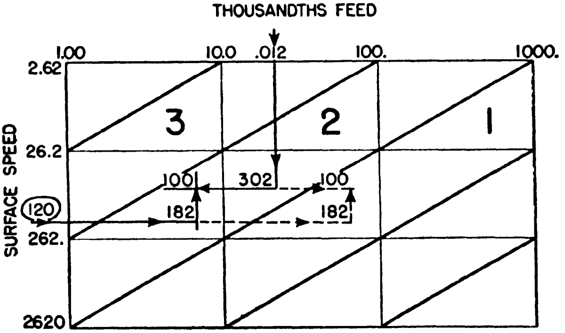


FIG. 91. A multi-unit chart arranged to establish decimal points.

DECIMAL POINTS

In the previous examples, the answers look strange because there should be some decimal points. This is the condition we find on our slide rules. Mr. K & E didn't put any on mine.

This shortcoming can be overcome in charts like these. The method is to repeat the scales. The unit cards mentioned earlier may be pasted together to form a large chart that gives proper recognition to decimal points. A line diagram of such a chart is shown in Fig. 91.

Across the top is a repeated scale for Feed in Thousandths of an Inch. Decimal points were added to the preprinted rows of numbers. Down the side is a repeated scale for Surface Speed in Feet per Minute. It is pointed off.

Diagonal lines pass through the chart to divide it into decimal-point bands. The ghost letters indicate how many of the three numbers shown must come after the decimal point. In one plant, these bands were lightly washed with different pale colors and then protected by a coat of lacquer.

To demonstrate the functioning of this multi-chart arrangement, two problems are solved. These show the shifting of decimal place in the answer caused by changing the location of the dimensions.

The basic machine operation time is

$$\text{Time} = \frac{\pi}{12} \times \frac{\text{Diameter} \times \text{Length}}{\text{Feed} \times \text{Speed}}$$

$$\text{Time} = \frac{\pi}{12} \times \frac{1\frac{13}{16} \times 3}{.012 \times 120} \tag{A}$$

$$= \frac{.262 \times 1.82 \times 3}{1.44}$$

$$= 1.00 \text{ Min}$$

$$\text{Time} = \frac{.262 \times 18.2 \times 3}{1.44} \tag{B}$$

$$= 10.0 \text{ Min}$$

As with a slide rule, the 182 and 302 could be either Diameter or Length. Just the same, my preference is to use the chart only one way. My suggestion is to relate Diameter to Surface Speed and Length to Feed. When one rule is followed, there is less chance for error.

MOUNTING DRUMS

A method of controlling the flexibility just mentioned is inherent in another gadget that is useful. We will describe it first, then come back to the control features.

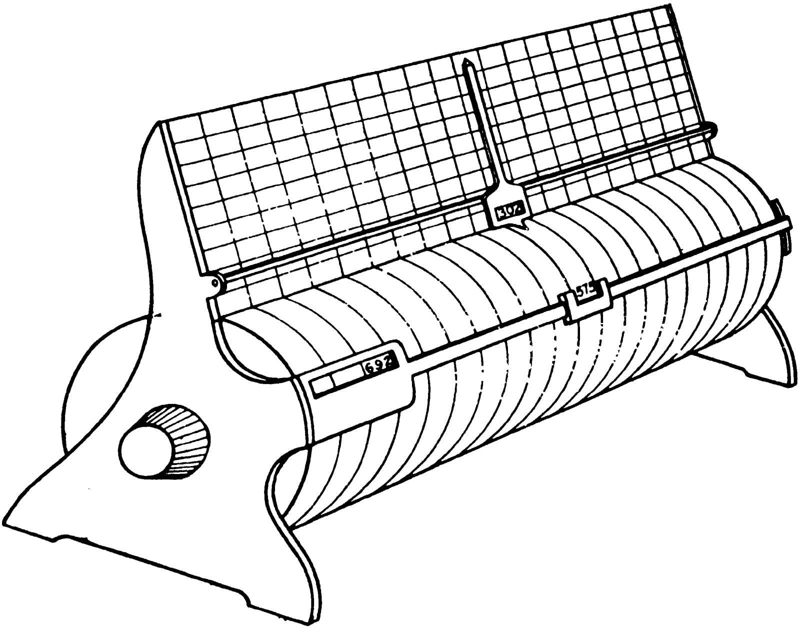


FIG. 92. Sketch of a drum for chart mounting. The vertical fixed chart is filled in with conditions and so are the bands at the left end of the drum.

Big charts are unhandy to use. When they get beyond a convenient size, they seem always to be under the papers you want to write on. If you have a big drawing to wrestle with also, then you do have your hands full.

One escape is to mount charts on drums. A picture of one application is shown in "Timestudy for Cost Control".[1] Another type I have seen is a very handy one. It was a big drum suspended horizontally over the desk. It was located about where the pigeonholes were above the old-fashioned roll-top desk.

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[1] Carroll, Phil, "Timestudy for Cost Control," 2d ed., p. 205, McGraw-Hill Book Company, Inc., New York, 1943.

A third variety is sketched in Fig. 92. Such a drum can be made by inserting circular wood plugs in the ends of a short length of large diameter pipe. Six- to ten-inch diameter is a good size range. In my opinion, it is better to choose a diameter large enough so that the chart goes about halfway around it.

In the sketch, the body of the chart and the surface speeds are around the drum circumferentially. The Feeds and the conditions that control them are placed on the stationary backboard. Then a slide moved horizontally across the drum is set for Diameter. The drum is turned until the Length comes to the slide rod. Then the time answer will appear in the slide opening. This action accomplishes the same results as tracing horizontally and vertically in the chart drawn on Fig. 91. In an arrangement like this, we can set up clear distinctions between Length and Diameter. Thus, we can control their interchange. This would be very important where, for example, Feed changed with increases in Length as the work became springy.

There are many uses for number charts such as have been explained here. These charts are easy to prepare. They can be made to perform any of the operations of multiplication and division in any number of factors. The values are expressed in numbers. Few charts have all these advantages combined.

With this, we complete the illustrations of chart making. But our next chapter will go into some detail about properly defining data application. We must not spend time making charts that will be misapplied because our definitions are not clear. Mistakes cost money.

CHAPTER 21

DEFINING DATA APPLICATION

Costs of standard setting vary greatly according to conditions. As used here, the term cost includes, beside timestudy effort, the expense and industrial relations losses caused by mistakes. But it excludes the excesses of the direct timestudy process over the standard data method.

Setting correct standards from data requires a knowledge of the work to be done. In a specific case, it may involve a study of the drawing and a reference to or the establishment of a method. Many other functions may be carried on by the standard setter. So much depends upon the plan of the organization. To confine our discussion, we will consider only the process of actually setting the standard.

In following the usual pattern, the timestudy man performs at least three steps:

1. He reads the element description.
2. He determines whether or not the element is necessary.
3. He applies the element, or starts to repeat these steps.

You may have seen two or more additional steps taken in the process. I have seen a "locate" operation prior to reading the element, and a "copy" procedure as part of applying the element.

These steps cost money. The most expensive one is that of determining when the standard applies. Usually, this requires decisions. And these decisions introduce inconsistencies. All these costs of time and error are reduced by grouping elements. Sure, it costs something to group the elements. Also, it takes time to select the right group from several. But the advantages so far outweigh the disadvantages that I urge you to do a great deal more grouping. You will get many more standards set per hour of timestudy time. You will gain much more standardization of method. You will maintain a consistency of application through changes in timestudy personnel. Quite a few paragraphs were given to this subject of grouping back in Chap. 17. We want to bring it up again, from the standpoint of application.

TIME TO READ

Our data has to be applied whether it is recorded in element details, in grouped combinations, or in chart form. Each subdivision of the complete standard necessitates the three, four, or five steps mentioned. Some of these may take zero or an insignificant amount of time. But from my observations, it seems that the proportion given to deciding increases with each improvement in the process. Let us analyze. If you reduce the fifth step by arrangements for circling instead of copying, then, as a percentage of the total, the deciding time has been increased. If you practically eliminate the "locate" operation by duplicating the data on one work sheet, the per cent of deciding is further increased. And so on.

"What about the reading?" you ask. Then you add, "There is no reading. The skilled man knows the data by heart." If that is so, you may skip this chapter. You already have thoroughly done what I want to suggest.

On the other hand, if your men take too long or create too many inconsistencies, some of the suggestions made here may help you.

TIME TO DECIDE

Reading and deciding are two quite different processes. In our work, there is the intermediate process of understanding. If we understand the description of the element, the group, or the chart, the deciding is almost instantaneous. That is the key to the first point I would like to make.

Understanding has two sides to it. We will dismiss the one that depends upon the capabilities of the individual. We are concerned with the part that hinges on the description. Is the wording such that it can be understood? Do we call some conditions "rough" or "smooth," "large" or "small"? Do we expect the standard setter to be a mind reader?

Incorrect and incomplete definitions are the wasters of time and money. Laziness is the cause, in my opinion. We can pass the buck by saying, "We had to get that department on standard by Monday." But we have wasted many a "pound of cure." We repeatedly pay some timestudy man to try to figure out what is meant by "tight fit" or "rigidly held."

These interpretations cost money. They produce inconsistencies, and you know all that happens thereafter. They occur because we don't or can't define the conditions. In either case, the standard setter is forced to decide. He cannot dodge the problem.

The same conditions exist in the shop. The mechanic has to figure out all the dimensions left off the drawing. This goes on every time a lot of pieces is produced. And scrap often results because errors are made in calculations. We try to reduce these expenses by getting more information on the drawings. As I express it, "It is cheaper to do the planning in the office than in the shop." Two fundamentals are involved. First is the application of the principle "each man to his trade." Second is the removal of setup items from repetition on each piece or lot. From this we conclude that

> *Repeated interpretations and calculations should be reduced by improving the design of the standard data.*

RUBBER DEFINITIONS

Examples of "rubber" definitions we see repeatedly in standard data are indicated by the following:

1. "Small," "medium," and "large" to classify size.
2. "Regular" and "irregular" to describe shape or condition.
3. "Rough" or "smooth" to indicate finish.
4. "50 pounds—over" (as an example of a wide-open limit) to measure weight.

The men who developed the standards know precisely what range in time values applies to the variables. They did not complete the job. They failed to set up limits that are understandable by those who will subsequently use the standard data. The important point to remember is that conditions change rapidly and memory fails quickly. The result is that the interpretations of such loose terms become distorted in both directions. Inconsistent standards are created. Also, our tendency to make larger and still larger products may cause the standard setter to continuously stretch the limits of such "rubber" definitions. Therefore, you have to do a good methods job in preparing standard data.

You must give more consideration to the time involved in the thinking process incident to using the working data than to the form itself. The most ingenious layout can be more expensive to use than a simpler one. Considerable time can be wasted in interpreting the specifications. Errors will be made. Obviously too, still more time will be lost in attempting to explain to operators and supervisors why a piece is "small" instead of "medium" and where the dividing line really lies. Unfortunately, the most extensive and honestly undertaken explanations may fail to convince the shop man that the standard setter does not have the privilege of making his own choices.

BORDER LINES

"Small" and "large" may be obvious terms in any one department, at the time the data is completed. Regardless, three defects are inherent in such inadequate descriptions:

1. What about sizes next month or ten years from now?
2. How small is a "small" piece and how large is a "large" one?
3. When does a small piece become large?

In timestudy language, these defects involve

1. Extensions of data as the product and method change.
2. Broad average classes that may be inseparable as time goes on.
3. Border lines that are left entirely to interpretations.

Practically all the information necessary to correct these definitions is available. It is in the timestudies, if they were taken correctly.

DEFINING DATA

Many of the loose definitions, typified here by "large" and "small," are for variable elements. Usually, these are analyzed and compiled as curves. In such instances, there is no excuse for anything less than specific definitions.

These can be obtained automatically when you use the curves or convert them to tables. Changing curves to numbers by 5 per cent or 10 per cent increments has been suggested. Whether you use these or uniform dimensional increments, there are definite sizes that correspond with specific standards. All that is necessary is to record both sets of related figures.

Part of the trouble may arise through attempts to oversimplify. This attitude sometimes creates classifications that are too broad.

My recommendation again is 5 per cent for repetitive and 10 per cent for jobbing. That means, there should be as many classes as there are increments between the low and the high standards in the range, plus one. More than an appropriate spread broadens the class. The average included is greater. Only a little more stretching brings us to such broad groupings as "small" and "large."

For definitions, you dare not rely on what I call "folklore"—word-of-mouth explanations. The dangers are emphasized by one of my favorite illustrations. Experience seems to indicate that we get about 60 per cent understanding when we try to teach timestudy. If in turn, the timestudy man succeeds in passing on the same per cent of understanding when he trains his successor, the second trainee has about 36 per cent (60 × 60) of the information originally imparted. Apply this to the interpretation of incomplete specifications and you can see how almost anything can happen.

DEFINING WORK DONE

Incomplete descriptions often result from another type of cause. How big is a burr? How much stock has a casting? How bent is a shaft to be straightened? How often should gauging be done?

To start this off, let me say that we must not accept things as they are. To do so, contradicts all the rules of progressive operation. Some men do. But they are looking for security or they do not view their work as a profession. They fail to realize that many operations done every day were started to overcome some defects. Often, this extra work continues only because someone forgot to stop it.

If we are to answer some of the everyday questions, we must establish normals. In the case of a burr, what is the reasonable minimum? What should we expect? An average is both worthless and unfair. It is of no value as a definition. It is unfair to the operator when conditions are worse. It is unfair to the consumer when conditions are better. Only by establishing a normal or standard condition can we overcome both difficulties.

It follows that when you set a standard amount of burr, stock, straightness, or inspection, you also establish the definition. You have specified the amount of work to be done for a corresponding time. Besides, you are in a position to measure from that base line to establish amounts of variation. And if you have set up your data correctly, you then know what to allow for the variations.

Extra allowances should vary with changing conditions. With progress, changes should be for the better more often than for the worse. These changes cannot be taken care of in an orderly way if an average has been used. When improvements are made on conditions that are averaged, either the savings are lost in "loose rates" or "rate cutting" is practiced. Neither condition is right. The only sound solution is to measure differences and apply standards accordingly.

> *Define normal conditions for the variable and base standards on normal, making allowances for measured variations from the normal.*

DIFFICULT SPECIFICATIONS

Some conditions seem almost impossible of definition. Color and finish are two common examples. It used to be that colors were matched only by comparisons. Even today, some people appear never to have heard of color measurements. Many shops have no way of defining smoothness of finish. And you cannot always have a sample. What good would come of comparing yesterday's loaf of bread with today's? Working toward some recording device is the only solution I can suggest for these measures and standards.

Finish problems can be greatly simplified by better engineering specifications. The single "f" mark should be abolished. All it means is that a cut is to be taken on the surface indicated. But that can mean any degree of machined surface.

What are needed are many modifications of "f." There should be as many classes as there are different finishes required. Or again, you can apply the 10 per cent idea. If there is a complete range of finishes, then there should be a designation for each 10 per cent change.

The method for producing each of the grades can then be established. Often, the feed to be used is the important element. Irrespective of the detail, the standard setter can be equipped with definitions that correspond with engineering finish marks. This can be worked out to almost completely eliminate interpretations and decisions regarding machining.

For certain types of conditions, you may find it seemingly impossible to compose definitions. One way out may be to

> *Relate definitions of standard data to the methods used to reproduce the quality specified.*

USE PICTURE SKETCHES

There is another approach to use in some cases that seem to defy word descriptions. Often, you can clearly indicate the conditions by means of pictures or sketches. One application is for specifying jig design. In this instance, the picture is worth a thousand words, even if the jig could be adequately described. It can be visually related to the current condition in very much less time than it would take to read a description. This acceptance however, does not mean that the word description should be omitted from the basic data. There it should be complete in every detail.

Here we are concerned with the production job of applying data rapidly. We want to reduce errors and time consumed by interpretations. In this effort, sketches can be helpful. They must either be more clearly apparent or take up less space than words, to have advantages. The latter qualification is difficult to meet. Usually, we side-step it. We put the sketches on a separate sheet. These are connected in the data with class names or numbers. This gets us back to decisions. The sketch that fits must be remembered or referred to.

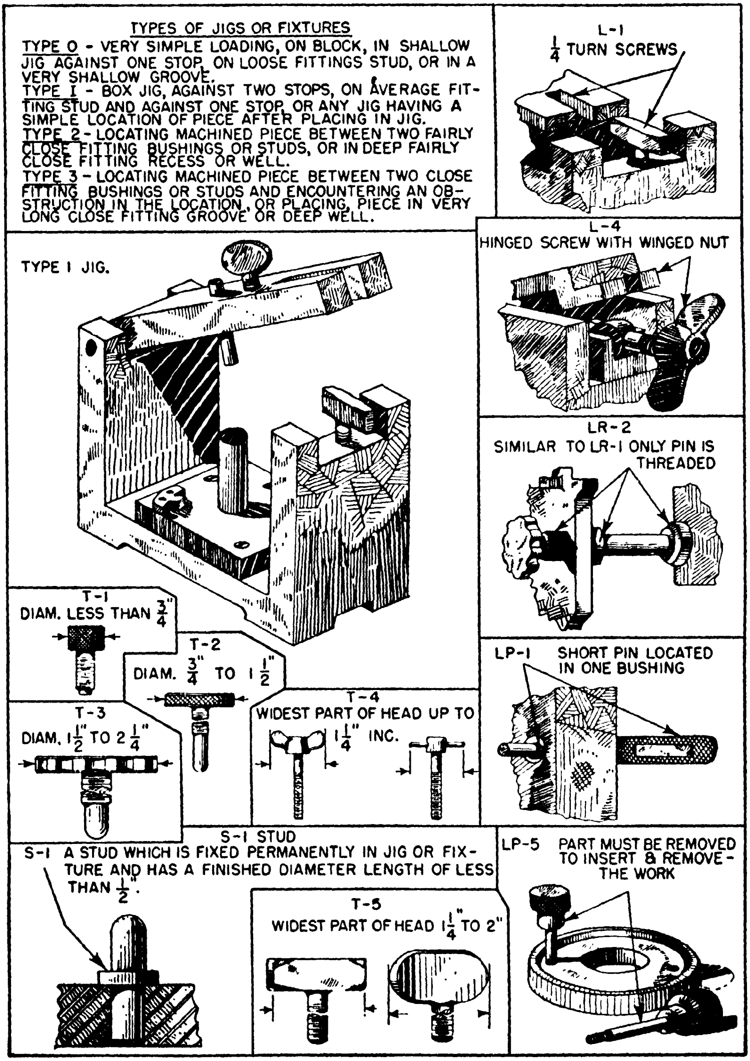
Space limitations usually force the separate recording of sketches. Figure 93 is typical. This happens because the standard requires only .08 square inch as compared with a minimum for a sketch of perhaps 1.0 square inch. As the number of standards applicable to one sketch increases, the space relationships improve. Therefore, under some conditions, we should carefully weigh the possibilities of including the sketches with the data. Such accomplishments will save time.

> *Use a sketch to portray conditions when words fail or too many are required.*

DRAWING DIMENSIONS

Time savings are made also when data can be defined in terms of drawing dimensions. This was brought out by example in Chap. 19. The principle involved is that of avoiding interpretations or computations. These details become very significant when standards are set for tailor-made products that have only one piece on the order.

To further point up the fundamental, let us illustrate. In drilling, we have to consider drill-point depth. This is usually taken as .3 × Diameter. Perhaps, also, some lead or overrun



TYPES OF JIGS OR FIXTURES

TYPE 0 - VERY SIMPLE LOADING, ON BLOCK, IN SHALLOW JIG AGAINST ONE STOP, ON LOOSE FITTINGS STUD, OR IN A VERY SHALLOW GROOVE.

TYPE I - BOX JIG, AGAINST TWO STOPS, ON AVERAGE FITTING STUD AND AGAINST ONE STOP, OR ANY JIG HAVING A SIMPLE LOCATION OF PIECE AFTER PLACING IN JIG.

TYPE 2 - LOCATING MACHINED PIECE BETWEEN TWO FAIRLY CLOSE FITTING BUSHINGS OR STUDS, OR IN DEEP FAIRLY CLOSE FITTING RECESS OR WELL.

TYPE 3 - LOCATING MACHINED PIECE BETWEEN TWO CLOSE FITTING BUSHINGS OR STUDS AND ENCOUNTERING AN OBSTRUCTION IN THE LOCATION, OR PLACING PIECE IN VERY LONG CLOSE FITTING GROOVE OR DEEP WELL.

L-1
$\frac{1}{4}$ TURN SCREWS
TYPE I JIG.
L-4
HINGED SCREW WITH WINGED NUT
LR-2
SIMILAR TO LR-1 ONLY PIN IS THREADED
T-1
DIAM. LESS THAN $\frac{3}{4}$"
T-2
DIAM. $\frac{3}{4}$" TO $1\frac{1}{2}$"
T-3
DIAM. $1\frac{1}{2}$" TO $2\frac{1}{4}$"
T-4
WIDEST PART OF HEAD UP TO $1\frac{1}{4}$" INC.
LP-1 SHORT PIN LOCATED IN ONE BUSHING
S-1 STUD
S-1 A STUD WHICH IS FIXED PERMANENTLY IN JIG OR FIXTURE AND HAS A FINISHED DIAMETER LENGTH OF LESS THAN $\frac{1}{2}$".
T-5
WIDEST PART OF HEAD $1\frac{1}{4}$" TO 2"
LP-5 PART MUST BE REMOVED TO INSERT & REMOVE THE WORK

FIG. 93. Sketches may be used to define standard conditions.

depth must be included. These distances greater than the drawing dimensions may be added in either of two ways. Usually, they are added to the drawing depth of the hole. Then the time assigned is for the total depth. This method requires one or more extra steps. There are several if the standard setter refers to auxiliary tables for drill-point lengths and overrun distances. Always, he must take account of the extra depths. If he forgets, an error is created.

The extras we are interested in are time values beyond those directly related to drawing dimensions. The arithmetic is like the "markup" in department-store pricing. Why not apply the same principle in standard data? Since drill point is $.3D$, it can be added in time in any data tabulated by diameter. Said another way, the drawing dimensions can be plotted against a time scale offset enough to add the requisite time.

The same applies to overrun. When this extra applies singly for blind holes and differently for through holes, two columns are suggested. One set of times would read directly including drill point and approach. The other would include in addition the break-through overrun. Two such columns might merge into one where the per cent difference becomes too small. The principle involved is to avoid the repetition of calculations by converting our data to drawing dimensions.

This improvement in method is one you can look for whenever dimensions are the starting information. You should try to eliminate steps taken to transform the drawing dimensions to some other figures. Common examples are Length × Width to compute Area and $.283 \times L \times W \times T$ to get Weight of steel. Charts may be worked out to save these computations. But you should consider going one step further. See if you cannot arrange the standard data to conform with the drawing dimensions. Then it can be applied directly. With such conformations, you have eliminated references, computations, and interpretations.

> *Arrange standard data so that direct-reading dimensions correspond with drawing sizes.*

RESTRICT INTERPOLATIONS

Along with the other problems of defining is one of rule making. You can permit or restrict the practice of interpolation. I would rule it out altogether.

If a table is interpolated, there is very little difference between using it and the basic curve. Actually, the curve might be the more efficient. So the gains to be derived from a table are lost if the standard setter spends time getting values in between chart readings. This takes too much time. It creates inconsistencies

If the standards in the table are too far apart, then correct the fault. If they are based on an acceptable increment, then forbid the procedure of computing standards that fall in between charted values. Insist that the standard setters follow this rule:

> *Use the charted dimension closest to the actual size in determining the standard to apply. For the midpoint dimensions, use the higher figure. Do not interpolate.*

BETTER DEFINITIONS

The details brought out in this chapter are suggestive only. It would take many pages to discuss the subject of defining as it should be explained. These brief comments are included simply as a reminder. They seem necessary because we have concentrated on the combining of standard data.

When we combine, we approach the total job standard. Frequently, the total is easier to describe than its parts. For instance, there may be 5,000 elements in the operation "Assemble Complete." We would understand the operation as a whole but have many questions about certain elements. Questions would surely arise about the start and finish of sub-assembly divisions that might be made of this total.

Consequently, it becomes necessary to define elements and element groupings. This may not be apparent to one who has always used the direct method of timestudy. In this process, whatever is excluded from one element or group is included with the element or group next to it. All are added together again in the final result.

Such is not the case with standard data. Each element is an entity by itself. It is set up in this way so that it can be used repeatedly thereafter, when it applies to the work being done. To make certain that it does apply, we must have correct and complete definitions of the work conditions.

Combining these introduces another variable—overlap. To avoid mistakes, we must define our conditions. But the definitions must be understandable. Mistakes avoided in one step can be created in the next by faulty interpretations. These are important considerations in themselves. An added reason here is that the time required to interpret poor definitions can waste away the economies of data grouping. They can consume the savings we have sought through better data charting.

Such details as we have emphasized in this chapter can be utilized to reduce standard setting costs. More constructively, savings in time can be used to give incentive opportunities to many who are limited to straight hourly pay. One principle we should follow is to incorporate calculations in the setup to eliminate them from the per piece operations. Another is to make our charts applicable through direct readings that conform with drawing dimensions. Over all is the perfection of definitions to minimize time and error. Understandable definitions are highly desirable in everyday standard setting and in signaling the necessities for revisions. We must make every effort to be absolutely fair in work measurement both in our day-to-day applications and those of the future.

CHAPTER 22

COMPARISONS OF DATA FORMS

Six commonly used methods for combining data have been described briefly in the foregoing chapters. Several examples of each have been worked out. Each form of data presentation has both advantages and disadvantages inherent in it. All these taken together make for confusion.

My personal preference is to point out one method and attempt to show why it is best. With charts, that preference happens to be the multi-variable expressed in numbers. But one method in charting cannot be the best. Relative costs are too important to be disregarded. So we must choose the form that most nearly fits our specific conditions at the time of application. This means perhaps, that all six types will be used in a total application. It means also that we may change forms as we move from one stage to another with the same data.

TIMESTUDY TOOLS

Each form has its field of application. Each is like a tool in a kit. In different situations, each may be substituted for the other. The limitations are your skill and patience after you weigh comparative costs.

A well-trained timestudy group should know how to construct and use all six. Without such skill, I don't see how the proper choice of method can be made. For that reason, we have tried to bring out the important factors that affect each type. In condensed form, these are summarized on Fig. 94.

Many of the comments given there are indicative only. Many concern intangibles that are difficult to evaluate. Even so, my hope is that you can be saved some mistakes by analyzing your problems with these advantages and disadvantages before you.

The important considerations are those of cost and understanding. These two are somewhat interdependent. Any form that requires endless explaining is costly. Any data that is not understood, even though repeatedly explained, is too expensive. And here we assume that lack of understanding is real and not political. It is sometimes difficult to distinguish between these two conditions. In general, we must assume that the "mystery" is a result of our failures in attempted explanations. We must repeat our efforts. We must use more understandable terms and forms.

ANALYSIS OF SIX FORMS OF DATA

Type	Advantages	Disadvantage
Curve	Already prepared Readily revised	Mysterious to shop Easy to make errors
Table	Standards in numbers Easy to circle	Variable increment Inflexible space
Equation	Takes little space Combined with ease	Very expensive to use High probability of error
Nomograph	Small space combined Easily solve many problems	Limited in application Too mysterious for many
Family	Simple to make Conserves space	Difficult to explain Probability for error
Multi-variable	Low cost per standard Standards in numbers	Expensive to revise Large space required

FIG. 94. In brief form, the advantages and disadvantages of all six forms are summarized.

FORMS FOR EXPLAINING

But do not conclude that the "mystery" of a form should eliminate it from use. In contrast, it may require that you use two forms. One is the most efficient form for the conditions of standard setting. The other is a form that can be understood when used for the purpose of explaining how standards are set.

The problem is similar to that involving Instruction Cards. Instructions are very necessary when *training* new people or *retraining* present employees. The emphasis is on training. Instruction Cards, films, visual aids, operation drawings, and all sorts of supplementary devices are desirable in training. But they become less and less important as knowledge and understanding are acquired.

The same line of reasoning applies to our standard data. Why should we use a cumbersome form every day simply because we will sometime need that form for explanatory purposes? Take a commonplace illustration. I have a strong feeling against the use of a slide rule in the shop. It is something "mysterious." We should use pencil and paper to do whatever calculating is necessary. Our computing should be carried on as slowly as the pace of our questioner requires. If he fails to keep pace, we must go back over the arithmetic and explanations. Understanding is what we are striving to attain. But the fact that this is the right procedure for an explanation in the shop does not make it obligatory for us to throw away our slide rules. We may make a thousand calculations in the office for every one we compute longhand in the shop.

Let's remember also that explanations must be repeated. There will always be the new supervisor, the new timestudy man, the new employee, and the new steward. All may have questions that should be fully answered. We must gain understanding in order to attain confidence.

TIME VARIES WITH FORM

If we agree about the importance of creating understanding, we can go on with considerations of efficiency. Let us continue our summary with a study of the times involved in using the same data presented in several forms. In two tests made, certain figures were accumulated. To obtain these figures, several men were asked to set five standards for five sets of conditions from data prepared in six forms. Each of the data forms used involved the same four variables. Actual times required to set these standards were recorded. The times tabulated from these tests are the averages of the five trials. The average times taken and the percentage each is of the lowest time are listed together with the forms of the data.

Type of Data Form	Minutes to Set One Standard	Per Cent of .42, Shortest Time
1. Equations	4.75	1130
2. Family of curves	1.06	253
3. Nomograph	.92	219
4. Two curves	.66	157
5. Two tables	.47	112
6. Four-variable chart	.42	100

These summarized results definitely point out the relative economies of the several forms of this four-variable data, considering only the time to set standards.

FORM INFLUENCES CONSISTENCY

In addition to the cost of time, you must concern yourself with the probability of error or inconsistency. Obviously, some of these methods include more opportunities for error than others. To bring out this phase, the per cents of variations from the unmistakable standards given by the four-variable chart are summarized as follows:

Data Form	*Per Cent of Variation*
1. Family of curves	130
2. Nomograph	107
3. Two curves	43
4. Equations	41
5. Two tables	16
6. Four-variable chart	0

These tests are by no means conclusive. They do not include a sufficient number of trials. They represent only the results from one set of data conditions. Probably, also, the results are distorted by lack of expertness with all the forms of data used in the tests. Nevertheless, the comparisons do add some factual information to the opinions that have been held. These are the first facts I have been able to assemble regarding the effect of data form upon standard setting costs and errors. While they are inadequate, they are significant and worthy of some study.

The chart combining all four variables into one answer is the only one of the six forms that was an actual example. The others were prepared to investigate differences. It should be evident, however, that when time and cost permit, charted number data can be used with less error and inconsistency.

WHAT TO DO

From the meager test results given, it would appear that charted data is the most efficient. This is true sometimes. It must be remembered, however, that this case example involved only four variables. Also, all four variables entered into every standard.

When more variables are added, the problem solutions become increasingly complicated. When some variables affect certain types of standards but not others, the charting is complex. Yet we need not take a "whole or none" attitude in approaching a solution. Nor should we limit the types of solutions to a few, either because we know only those or because we settle into routines. Our approach should be the same as with methods improvement. There is a better way. "Will it pay for itself in a reasonable time?" we must continually ask.

Let me repeat, "We do not perform all lathe work on an automatic." In fact, many of the job shops I have worked with do not own such machines. The quantities run are too small to permit the use of that type of equipment. In its simplest terms, the setup cost per piece would be prohibitive. So it is with our methods study of charting.

CHART PERFECTION

The test results show that it is faster to trace through four charted variables than through two pairs in separate tables. Most of the difference is consumed in writing and adding two answers. In addition, there were 16 per cent more errors created by the writing and adding. This clearly points out that the ideal solution is a chart showing total standards.

Notice also that both time and error are reduced when numbers are used instead of scale divisions. While these results confirm our expectations, the degree should be discounted. Remember that those who participated in the tests were not equally expert in using all six forms of data. Make certain that you recognize the necessity for prior training before you conclude to accept or to reject any specific forms of data.

We want the best. We want to set more standards per man-day with zero mistakes. But the ideal solution is not always attainable. It may cost too much. It may be too large and unwieldy. Therefore, we must balance advantages against disadvantages. We must weigh the setup cost per standard against the savings in cost per standard. We must seek the economical solution.

REPETITIVE MEASUREMENT

Do not let this cost-finding principle cause you to postpone methods changes. There is ample room for improvement, if what I have seen is a representative sample. We can make many savings in the cost per standard without having to give much attention to the expense involved.

It appears to me that too often we use the standard-setting methods established for repetitive operations. This is fallacious. With large quantity production, the cost per standard is relatively unimportant. Almost any reasonable cost may be insignificant in comparison with the gains achieved. I might add also, that the time taken to set the standard is usually very much longer than it need be. Urgency is lacking. This is because the operation will be continuing next week, next month, and perhaps next year.

At the opposite extreme is the one-piece order. For this, we set the standard in advance or the work is completed without incentive opportunity. In between is where the bulk of industry lies with respect to quantity. Thousand-, hundred-, ten-, and fewer-piece lots are what we must measure. Large quantity manufacture is not our concern for two reasons. First, most of this work has been measured for years. Second, as already mentioned, the cost per standard is very small relatively. Only where time and cost per standard are under high pressure can the methods outlined in this book be most helpful.

QUANTITY FACTORS

Incentives must pay for themselves. Of course, the returns should include intangibles like employee satisfaction, advancement, and objective measurement of individual skill and ability. Yet, the success of the company is finally determined by profit making. In a large degree, this success results from methods used. Methods include equipment and tooling and also planning, quality control, and incentive, to name a few.

All methods cost money to install and to operate. Each should make a profit. If each is not self-supporting, it consumes part of the gains made by the others. Each has its own break-even point with respect to quantity. One portrayal of this effect is shown in Fig. 95. The diagram indicates that we can economically spend more and more for method improvements as quantities increase, up to a point. The total cost of method plus time declines until a saturation point is reached. Then the total begins to rise. This is often true generally.

But our two curves are based on one type of method improvement. Should we change to another, two more cost curves would be introduced. Either might be higher or lower than its corresponding curve in this diagram. And this applies to our analysis of charting data. The important difference is that quantity in our thinking is number of standards set, not pieces on the order. Also, as with tooling methods, we must consider the probable number of standards to be set before a revision in data makes our chart obsolete.

CHOOSING METHODS

Our criterion is the total cost per standard. This is made up of the prorated cost of our chart plus the cost of one standard. These considerations are limited solely to the per standard cost.

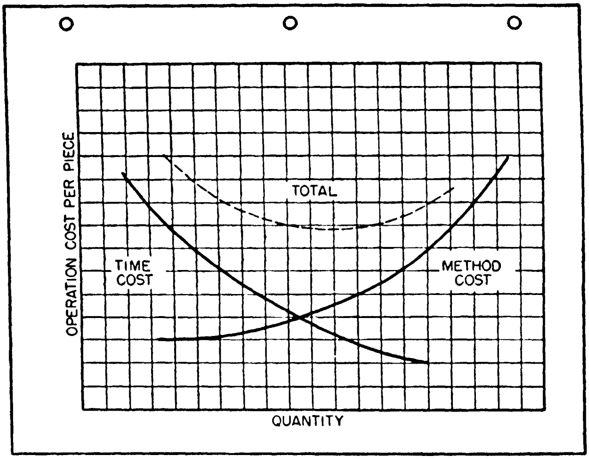


FIG. 95. Within limits, we can afford to spend more money for methods improvement as quantities rise.

They should not include costs of the many other functions that may be carried on by the timestudy man. Our best analysis may show that we can afford an intricate chart for setting standards on one-piece orders. At the opposite extreme, it may cause us to conclude that very simple methods are least expensive for a certain condition. These are tangible cost considerations. But in addition, we must reckon with errors created and explanations to be made. These are difficult to appraise.

Unfortunately, I can offer no more factual data than the scant bits previously given. More information would be helpful, but it could serve only as guideposts. There is too much individualism in each of the tailor-made solutions that is caused by circumstances.

And yet, to offer some indicators, I feel obliged to include a rough sort of guide. You may find assistance in the "guesstimated" chart, Fig. 96.[1] In this the attempt has been made to suggest the type of solution to use according to the complexity of the standard and the number to be set.

EXTENDING INCENTIVES

Underlying all of our concern about methods and their costs is the effort to extend incentives. More and better incentives are needed. Many people have no incentive opportunities at all. Many types of work go on day after day with no form of measurement or extra reward.

Application of Typical Forms of Working Data

Number of Standards	Type of Operation			
	Simple	Normal	Complex	Very Complex
Thousands. . .	Element	Equation	Table	Table
Hundreds. . . .	Equation	Table	Multi-variable	Multi-variable
Tens.	Table	Multi-variable	Multi-variable	Family
Occasional. . .	Curve	Multi-variable	Nomograph	Formula*
Rare.	Curve	Family	Nomograph	Formula*

**Note.* The term "formula" is used to distinguish an equation that has been determined from the plotting of a large number of total standards.

FIG. 96. A rough guide suggesting the type of solution suitable to the conditions.

From my point of view, we need to reduce the costs of timestudy results so we can get wider application. The problem is analogous to that of every business with respect to its product. The lower the cost, the wider the distribution.

To gain our objective, we should analyze and improve our timestudy methods. We should effect economies. We should utilize all the principles of repetitive application that we can borrow from manufacturing methods. We should devise "tooling" that brings about the lowest total cost.

In this effort, the methods described in preceding chapters have some place. They suggest different types of "tooling" that can be used to increase production. You can utilize at least some of the ideas to make timestudy more constructive.

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[1] Carroll, Phil, "Timestudy for Cost Control," 2d ed., p. 154, McGraw-Hill Book Company, Inc., New York, 1943.

The methods brought out are by no means all inclusive. They are limited principally to those designed for standard data presentation. You might say that they are the "jigs and fixtures" for data application. Those tools we find very useful in the shop. Similarly, better tools should be helpful in raising timestudy productivity. If they assist you, some gains will have been made. My hope is that you will find it helpful to you to put some of the ideas to work with success in reducing the costs of timestudy and in greatly extending incentive opportunities.

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